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# ORIGINAL ARTICLES.

## Recent Work on the Phacopidae.

By F. R. COWPER REED, Sc.D., F.G.S.

*(Concluded from p. 322.)*

### PART II.

### REMARKS ON SOME OLDER GENERA AND SUBGENERA OF THE PHACOPIDAE.

IT is worth while to examine the value and definition of certain of the older generic or sub-generic groups, for there is much difference in the usage of the terms, and in the interpretation of their rank and value. This is especially the case with *Acaste* and *Phacopidella*, for the author of the latter name wrongly included in it such forms as *Ac. downingiae* and others of a diverse type, though they differed in important particulars from the species *Ph. glockeri* Barr. which he chose as the type of *Phacopidella* as above observed (see *Glockeria*). Other new and old generic terms appear to have been also used in too broad a sense, and there is no general agreement as to their limitation.

#### (*a*) *Phacopidella* Reed, 1905.

All the species which do not conform in structure to the type-species *Ph. glockeri* Barr. must be removed from it, and it must be reiterated that *Acaste downingiae* Murch. is quite distinct.

Raymond[1] recognized this in 1913, and Perna[2] in 1915, the latter strictly limiting the name *Phacopidella* to the type-species and to its closely related forms. McLearn[3] in 1918, Richter[4] in 1923, and Kozlowski[5] also in 1913, similarly restrict it. With this view, the present author is in complete agreement. But he does not assent to McLearn's application of his name *Dalmanitina* to *Acaste downingiae* and its allies, nor to Richter's inclusion of such forms as Perna's *Denckmannia limaria, Ph. volborthi* Barr., and *Ph. ductifrons* Richt. in *Phacopidella.*

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[1] Raymond, *Ottawa Naturalist*, vol. xxvi, 1913, p. 6 (reprint).

[2] Perna, *Mem. Com. Geol. Russ.*, N.S., Livr. 138, 1915, p. 50.

[3] McLearn, "Revision of some Phacopid genera": *Ottawa Naturalist*, vol. xxxii, 1918, p. 33.

[4] Richter, *Senckenbergiana*, Bd. v, Heft 3–4, 1923, pp. 134–43.

[5] Kozlowski, *Annales de Paléont.*, xii, fasc. 1, 1923, p. 28.

Williams and Breger,[1] while accepting the name *Phacopidella* and giving to it generic rank, consider that two sections are "easily demarcated" in it, one of which is typified by *Ph. glockeri* Baur., and the other by *Ph. anceps* Clarke. But they include in the first section such diverse forms as *Ph.* (*Acaste*) *downingiae* Murch., and *Dalmanites* (*Anchiopella*) *africanus* Salter. In the second section "only the third pair of lateral lobes is developed, the first and second pairs being either entirely obliterated or exceedingly faint", and they would include *Ph. brasiliensis* Clarke of the Lower Devonian of Brazil, which is taken by McLearn (op. cit., 1918, p. 33) as the genotype of *Phacopina.* Clarke[2] had previously advocated this usage of *Phacopidella*, but as above remarked, it cannot be accepted, and later European palaeontologists use the term *Phacopidella* in a more restricted sense.

The Richters[3] have recently re-defined *Phacopidella* and accorded it generic rank in the *Dalmanitinae*, but they include *Glockeria* and *Denckmannia* (see below) in it as well as several Upper Devonian forms. The present author believes that they employ the name *Phacopidella* in too extended a sense, some of the species which they put under it belonging probably to *Phacopina.*

### (*b*) *Acaste* Goldfuss, 1843. (= *Acastina* nom. prop.)

In the case of *Acaste* Goldfuss, 1843, which the present author rejected in 1905, because of the pre-occupation of the almost identical name *Acasta*, the type is *Calymene downingiae* Murchison, and much confusion has arisen through the unfortunate inclusion of this species in *Phacopidella.* McLearn,[4] as above stated, put this species in the subgenus *Dalmanitina* with the Bohemian *D. socialis*, which is the species chosen by the author as the type form of *Dalmanitina*, and a great deal of misuse of the names has hereby originated. Thus Barrois[5] adopted McLearn's conclusions and used *Dalmanitina* as a substitute for *Acaste.* Richter in 1923 pointed out that *Acaste* has a characteristic *Dalmanites*-like head, all three glabellar furrows being developed, but the pygidium is nevertheless *Phacops*-like, and quite different to that of *D. socialis.* The author cannot therefore accept McLearn's application of the name *Dalmanitina.* The name *Acaste* (if retained in spite of its predecessor *Acasta*) must be strictly limited to the trilobites of the type of *A. downingiae*, the characters of which species need not here be given, as it is such a well-known Wenlock form. It is curious that Wedekind[1] should label as *Acaste* Portlock's species *Phacops brongniarti*, for it is usually acknowledged that it belongs to *Pterygometopus*, and the author in 1905 and Kozlowski[2] and King[3] in 1923, put it in the latter subgenus. Raymond[4] and Warburg[5] also accept this reference. But there has been still further unjustified latitude in the interpretation of the subgenus *Acaste*, for in 1913 Kozlowski[6] remarked that it played an important part in the Devonian faunas of South America, though in Europe the subgenus is limited to the Silurian, and he would include such forms as *Cryphaeus convexus* Ulrich (following the example of Knod[7] and Groth[8]), and *Acaste devonica* Ulrich, *Acaste acutiloba* Knod (= *A. verneuili* D'Orb.), and *A. lombardi* Kozl.[9] But *Cr. convexus* Ulr. is referable either to *Acastella*[10] or to *Phacopina*, and *A. lombardi* and *A. devonica* probably to the latter, while *A. verneuili* has a pygidium with two pairs of marginal denticulations like *Pennaia* (q.v.). It is undoubtedly the case that certain species referred to *Acaste* have a Dalmanitid type of head-shield, and if Richter is right in ascribing certain species of the Mütterschiefer (*A. henni* Richt.[11] and *A. schmidti* Richt.[12]) to *Acaste* we should have to admit that the subgenus really extends up into the Devonian. But it is much more probable that these species should be placed in the subgenus *Phacopina*. Kozlowski[13] in 1923 regarded *Phacopina*, *Anchiopella*, and *Proboloides* to be subgenera of *Acaste*, but this cannot be regarded as justifiable.

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[1] Williams and Breger, "Fauna of Chapman Sandstone": Professional Paper 89, *U.S. Geol. Surv.*, 1916, p. 287.

[2] Clarke, *Bull.* 107 *New York State Mus.*, 1907, p. 106.

[3] R. and E. Richter, *Abh. preuss. geol. Landesanst.*, N.F., Heft 99, 1926, p. 200.

[4] McLearn, op. cit., 1918, p. 32.

[5] Barrois and others, *Mem. Soc. Geol. du Nord*, vi, ii, Fasc. 2, 1920, p. 120.

The typical *Acaste* does not seem to occur in the austral fauna. If a new subgeneric name is regarded as necessary for this well-marked group of species in order to avoid confusion with *Acasta*, the name *Acastina* may be suggested.

### (*c*) *Portlockia* McCoy, 1846.

In 1906 the present author[14] put the species *Ph. elegans* Sars and Boeck and *Ph. stokesi* M. Edw. in the subgenus *Phacopidella*, but this is incorrect if we accept the strict limitation of the latter name.

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[1] Wedekind, *Abh. k. preuss. geol. Landesanst.*, N.F., 69, 1914, p. 28, text-fig. 4.

[2] Kozlowski, op. cit., 1923, p. 27, footnote.

[3] King, *Q.J.G.S.*, vol. lxxix, 1923, p. 506, pl. xxvi, figs. 4, 5.

[4] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lxvii, 1925, p. 162.

[5] Warburg, *Bull. Geol. Instit. Upsala*, vol. xvii, 1925, p. 399.

[6] Kozlowski, *Annales de Paléont.*, viii, 1913, p. 15.

[7] Knod, *Neues Jahrb. f. Miner.*, Beil. Bd. xxv, 1908, t. xxi, fig. 4.

[8] Groth, *Bull. Soc. Geol. France*, ser. IV, vol. xxii, 1912, p. 607, pl. xviii, fig. 4, 4*a*, pl. xix, fig. 1.

[9] Kozlowski, op. cit., xii, 1923, p. 48, pl. iv, figs. 1–6.

[10] Reed, *Ann. S. Afr. Mus.*, xxii, 1925, p. 138.

[11] Richter, *Jahrb. k. preuss. geol. Landesanst.*, Bd. xxxvii, i, Heft 2, 1916, p. 252, t. xxvii, figs. 1–3.

[12] Ibid., p. 252, t. xxvii, figs. 4–6.

[13] Kozlowski, op. cit., 1923, pp. 49–53.

[14] Reed, *Lower Palaeoz. Trilob. Girvan*, pt. iii, pp. 154–6.

McLearn[1] has recognized their different character and would consequently revive the name *Portlockia* McCoy, 1846,[2] as a subgenus of *Phacops*, having *Ph. stokesi* as the type-species. To this subgenus thus belongs also its variety *uskensis* described by the author in 1916.[3] McCoy's definition of *Portlockia* was as follows (op. cit.) :—

"Cephalothorax truncato-orbicular, lateral angles not produced into spines ; glabella large, clavate, widest in front, reaching to the margin, contracting to a narrow neck behind ; neck-furrow strong ; cheeks rather small, triangular, convex ; eyes large, reniform ; abdomen of thirteen segments, rounded at their extremities, anterior margin sharpened for contraction ; pygidium semi-elliptical, of seven simple segments, margin entire, smooth." Type-species *Ph. sublaevis* McCoy, Silurian, Co. Galway.

*Ph. sublaevis* is generally considered to be inseparable from *Ph. stokesi* M. Edw., and is given as such in most synonymies.[4] *Ph. musheni* Salt. is another allied species which must be placed in *Portlockia*, and it seems that Wedekind's[5] subgenus *Pterygometopidella* is inseparable from the latter.

The Richters, however, in 1923[6] considered that *Portlockia* was a synonym of *Phacops* sens. str., and that consequently *Ph. stokesi* was not a separate subgeneric type. Foerste[7] had in 1919 adopted McLearn's recognition of its independence and described a new American species under the name *Ph.* (*Portlockia*) *mancus*, mentioning that *Ph. landwerki* Weller was another closely related species. As regards its origin Foerste thinks that *Portlockia* was derived from some early species of *Pterygometopus*. McLearn[8] in 1924 adhered to his previous opinion of the independent subgeneric rank of *Portlockia*, and there is no doubt that it can hardly be considered identical with *Acaste*, the structure of the glabella and development of its furrows departing considerably from that type. The peculiar basal ring on the glabella, with the basal lobes reduced to mere tubercles is a distinctive feature.

In 1907 Schmidt[9] apparently used the subgenus *Phacops* in the same sense as *Portlockia* as above defined, for he put in it *Ph. elliptifroms* Emmr. from Stages G, H of the Baltic Provinces, a species which is allied to *Ph. elegans* Boeck and *Ph. stokesi* M. Edw.

### (*d*) *Dalmanitina* Reed, 1905.

This subgeneric name was suggested by the author in 1905, with *D. socialis* Barr. as the type, a British variety of which termed

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[1] McLearn, op. cit., 1918, p. 34.

[2] McCoy, *Silur. Foss. Ireland*, 1846, p. 50, pl. iv, fig. 13.

[3] Reed, *Proc. Cottesw. Nat. Field Club*, xix, pt. ii, p. 169, pl. viii, figs. 13–16.

[4] Woodward, *Catal. Brit. Foss. Crust. Brit. Mus.*, 1877, p. 54.

[5] Wedekind, *Zeitschr. deut. geol. Gesell.*, lxiii, 1911, p. 324.

[6] R. and E. Richter, op. cit., 1923, p. 135.

[7] Foerste, *Ohio Journ. of Science*, vol. xix, No. 7, 1919, p. 399, pl. xviii, fig. 3.

[8] McLearn, *Mem.* 137, *Geol. Surv. Canada*, 1924, pp. 170, 171, pl. xxviii, figs. 1–4.

[9] Schmidt, *Rev. Ostbalt. Silur. Trilob.*, Abt. vi, 1907, p. 1, t. 1, fig. 1.

*argentea*[1] had been previously described from the *Orthis argentea* beds of Haverfordwest. *Ph. robertsi* Reed[2] from the Upper Bala of South Wales, was regarded as also referable to this subgenus. The Llandovery species *Ph. weaveri* Salt. was definitely placed in it by the author in 1909,[3] and it is possible that *Ph. asteroideus* Reed[4] from the Drummuck Beds of Girvan may belong to it. Troedsson[5] correctly placed the British representatives of *Dalmanites eucentrus* Ang.[6] and *Dalmanites mucronatus* Ang. in this subgenus, and the present author, in 1905, had recognized the close relations of the latter species to *D. appendiculatus* Salt.

It is probable that *Ph. recurva* Linnarss.[7] and *Ph.* aff. *incertus* Desl.[8] from the Slade Beds belong to a subgroup, but they are only known at present by their pygidia. McLearn[9] in 1918, as above mentioned, and again in 1924,[10] used the name *Dalmanitina* in much too wide a sense, and Barrois[11] in 1920 followed suit. But Richter[12] corrected their mistaken ideas in 1923, by re-establishing and separating *Acaste* and *Phacopidella*, as above mentioned. On the other hand McLearn[13] in 1924 refers to *Dalmanites* the Nova Scotian trilobite which he identifies with *Phacops weaveri* Salt., stating that this species is intermediate between *Dalmanites* and *Dalmanitina*, and he compares it with *Acaste downingiae* and *Dalmanites caudatus* Brünn. But it is difficult to say if it is identical with the British species, for McLearn's figured specimens show much distortion; the pygidium is indeed more like that of *Ph. asteroideus*. The Lower Devonian specimen from Canada which Salter[14] doubtfully identified with *Ph. weaveri* was removed by Clarke[15] in 1908 to a new species and subgenus (*Probolium biardi*).

In a recent paper by Raw[16] it is considered that *Dalmanitina* is the most primitive subgenus of *Dalmanites*, but he puts *Dalmanites hausmanni* Brongn. in this subgenus, and regards as perhaps the most primitive Phacopid *Pterygometopus hunteri* Reed [1] from the Balcletchie Beds of Girvan; but this view may be seriously disputed.

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[1] Reed, GEOL. MAG., Dec. V., Vol. I, 1904, p. 383, Pl. XII Fig. 2.

[2] Ibid., Dec. V, Vol. I, 1904, p. 106, Pl. V, Figs. 1–7.

[3] Ibid., Dec. V, Vol. VI, 1909, pp. 69–73.

[4] Id., *Lower Palaeoz. Trilob. Girvan*, Suppl., 1914, p. 53, pl. viii, figs. 10–12.

[5] Troedsson, *Lunds Univ. Arsskr.*, N.F., Avd. 2, 1918, Bd. xv, No. 3, pp. 57–75.

[6] Olin, *Kongl. Fysiogr. Sällsk. Handl.*, Bd. xvi, No. 3, 1906, p. 41, t. 1, figs. 1–3.

[7] Olin, op. cit., p. 42, t. 1, figs. 4, 5.

[8] Reed, op. cit., 1904, p. 384, pl. xii, fig. 4.

[9] McLearn, *Ottawa Naturalist*, vol. xxxii, 1918, p. 32.

[10] Id., "Palaeont. Silur. Arisaig": N.S., Mem. 137, *Geol. Surv. Canada*, 1924, p. 166.

[11] Barrois, op. cit., 1920, p. 120.

[12] Richter, *Senckenbergiana*, Bd. v, Heft. 3–4, 1923, pp. 134–41.

[13] McLearn, *Mem.* 137, *Geol. Surv. Canada*, 1924, p. 169, pl. xxvii, figs. 7–10.

[14] Salter, *Mon. Brit. Trilob.*, 1864, p. 57, fig. 15.

[15] Clarke, *Mem.* 9 *New York State Mus.*, pt. i, 1908, p. 129, pl. vi, figs. 1–12.

[16] Raw, *Q.J.G.S.*, vol. lxxxi, pt. ii, 1925, p. 279.

The Upper Silurian trilobite *Dalmanites logani* Hall, which McLearn [2] has referred to *Dalmanitina* in his extended use of that name may more probably be placed in *Acastella* (see above), and in some respects resembles *Phacopina*.

### (*e*) *Dalmanites* Barrande, 1852.

This name is now used in a generic sense by most authors, but there is little agreement as to how many subgenera may be recognized in it. Wedekind [3] only acknowledged *Dalmanitina* Reed and *Hausmania* Hall and Clarke as valid, and he put *Cryphaeus* as a subgenus of *Acaste*, which is a curious association. Kozlowski [4] recognized the following seven subgeneric groups: *Dalmanites* sens. str. (= *Hausmannia*), *Dalmanitina*, *Cryphaeus*, *Cryphina*, *Coronura*, *Odontocephalus*, and *Corycephalus*.

Gürich [5] preferred to use the term *Dalmania* in place of *Dalmanites*, and regarded *Odontochile* Corda as a subgenus and equivalent to *Hausmannia*. McLearn in 1924 (op. cit.) used *Dalmanites* and *Dalmanitina* as terms of equal and generic rank, and Barrois [6] in 1920 considered *Cryphaeus* to be a distinct genus.

The present author [7] in 1925 employed *Dalmanites* in a generic sense, with *Anchiopella*, *Corycephalus*, *Hausmannia*, *Proboloides*, *Acastella*, and *Cryphaeus* as subgenera represented in the Bokkeveld fauna.

In America we find that *Synphoria* Clarke, is sometimes used [8] as a subgenus of *Dalmanites*, with *D. stemmatus* Clarke as the type, and that the distinct genus *Chasmops* is still employed in a subgeneric sense for such species as *Dalm. anchiops*.[9]

Clarke [10] has made some interesting and suggestive observations on the *Dalmanites* of the Lower Devonian of the boreal faunas, particularly noticing that their decline is expressed by concomitant development of cuticular excrescences affecting the head and pygidium chiefly, but not involving those parts to an equal degree. "In *Dalmanites* the modification of the head-shield is distinctly earlier than a similar adornment of the tail. *Cryphaeus* and *Coronura* are forms with pygidial modification in which the tail furnishes the generic characters, and these do not appertain to the earliest Devonic faunas." He has given figures of a series of head-shields, showing the variation in the frontal border from the normal regularly rounded type (*Hausmannia* or *Odontochile*) to the *Probolium* condition with a long median rostrum, and another series showing stages of development of the border in a group of species and subgenera from a condition of entire smoothness to one of complete crenulation (*Corycephalus*), all occurring in the early Devonic of North America.

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[1] Reed, *Lower Palaeoz. Trilob. Girvan*, 1914, p. 52, pl. viii, fig. 8.

[2] McLearn, op. cit., 1924, p. 167, pl. xxvii, figs. 3–6.

[3] Wedekind, *Abh. preuss. geol. Landesanst.*, N.F., Heft 69, 1914, p. 39.

[4] Kozlowski, op. cit., 1923, pp. 26–36.

[5] Gürich, *Leitfossilien*, Devon, 1909, p. 159.

[6] Barrois and others, op. cit., 1920, p. 122.

[7] Reed, *Ann. S. Afr. Mus.*, xxii, 1925, pp. 122–48.

[8] Ohern and Maynard, *Geol. Surv. Maryland*, Lower Devonian, 1913, (Baltimore), p. 503, pl. xciii, fig. 3.

[9] Ibid., p. 508, pl. xciii, fig. 5.

[10] Clarke, *Mem.* 9 *New York State Mus.*, pt. i, 1908, pp. 131–4, figs. 1–11 and 12–20.

It may be here mentioned that Kozlowski does not admit that the rostral point in *Probolium* and *Proboloides* is of value for a natural grouping of the species, as it is an independent development at different periods in several small branches of the family, and he puts *Proboloides* as a subgenus of *Acaste* and as representing an austral development parallel to the boreal *Probolium*, which is a Dalmanitid. The same author is inclined to doubt the taxonomic value of the cephalic or pygidial ornaments on which the subgenera of *Dalmanites* are based, but they seem to mark an expiring outburst of activity in variation, such as is seen in the case of other families.

### (*f*) *Synphoria* Clarke, 1900.

There seems to be some doubt as to whether Clarke discarded this name in 1913 (op. cit., pp. 148, 157) as a subgenus, and only employed it to designate a group comprising several subgenera of doubtful affinity, with only the common characteristic of the coalescence of the anterior and middle lateral lobes of the glabella. But in 1900,[1] when he proposed and discussed the name, he definitely stated that this coalescence was of " real significance in the anatomy of the animal " and that it distinguished a considerable number of forms from the normal *Dalmanites* in which the division of the first and second glabellar lobes was complete, and that it " may prove of subgeneric significance ". He observed, however, that this feature is present in species with " much diversity of marginal cephalic ornament ", some of which on the strength of the latter had been already given subgeneric rank (*Odontocephalus*, *Coronura*, *Corycephalus*). The species first described with the appellation *Synphoria* is put down as *Dalmanites* (*Synphoria*) *stemmatus* Clarke [2] in the usual subgeneric manner, and thus must be recognized as its type. It occurs in the Oriskany of New York, and has merely small rounded crenulations or blunt processes round part or the whole of the margin of the cephalon.

A peculiar species of *Dalmanites* was described in 1900 by H. H. Thomas [3] from the Wenlock Shales as *Phacops* (*Dalmania*) *coronata*, which has a series of short sharp spines projecting from the margin of the head-shield. Probably it belongs to the same subgenus or group as this species of *Dalmanites*.

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[1] Clarke, " Oriskany Fauna of Becraft Mountain," *Mem.* No. 3, vol. 3, *New York State Mus.*, 1900, pp. 17–19.

[2] Ibid., p. 15, pl. i, figs. 6–16, pl. ii, figs. 1–2.

[3] H. H. Thomas, *Q.J.G.S.*, vol. lvi, 1900, p. 616, pl. xxxv, figs. 1–3.

(*g*) *Cryphaeus* Green, 1837. (= *Asteropyge* Hawle and Corda, 1847.)

With regard to *Cryphaeus* there has been considerable difference in the usage of the name, and in the conception of its taxonomic rank. Gürich in 1909 (op. cit., p. 160) used it in a generic sense, and so did Clarke in 1913 (op. cit., p. 108). The latter remarked that " If *Cryphaeus* means anything, it signifies a dalmanitid structure characterized by a glabella with unfused lateral lobes (*Hausmannia* type) occurring in conjunction with a pygidium bearing five pairs of lateral ribs, deeply sulcate in earlier forms, faintly so in later and final phases, and bearing five lateral projecting lappets on each margin with a central one at the caudal extremity. . . . . From this genus should be eliminated all species based on parts other than pygidia having the features indicated, and among these pygidia the size and shape of the marginal lappets have a lower specific value than is commonly ascribed to them." But he also remarks that as far as cephalic structure is concerned, *Cryphaeus* is in effect a true *Odontochile* (*Hausmannia*). Barrois and Pruvost [1] in their description of the species *Cr. michelini* Rouault, from Lievin, keep strictly to the above limitations of the genus.

But Wedekind in 1914, as above noticed, put *Cryphaeus* as a subgenus of *Acaste* amongst the *Phacopidinae* instead of as usual amongst the *Dalmanitinae.*

The author in 1905 contended for the use of the term *Asteropyge* Hawle and Corda, 1847, in place of *Cryphaeus* Green which was pre-occupied, but the latter name seems too firmly implanted in geological literature to be uprooted, though Asselberghs [2] has recently adopted *Asteropyge* in describing the Devonian species *Cr. punctatus* Stein, and the Richters [3] have likewise reverted to this name, using it in a generic sense and recognizing two subgenera *Asteropyge* sens. str. and *Metacanthus* amongst the Upper Devonian representatives. The author [4] has himself returned to the name *Cryphaeus* in describing the South African trilobites from the Bokkeveld Beds, but has used the term to denote a subgenus of *Dalmanites.*

We may here draw attention to the remarkable points of resemblance between the cephala of *Dalmanites* and *Paradoxides* in spite of the important morphological differences in their structure, such as particularly in the nature of the genal spines of the two genera, as Raw [5] has recently emphasized; for in the case of *Dalmanites* we have the homologues of the metacranidial spines of the Cambrian genus which are completely different in their origin and relations to the parial (genal) spines of the Opisthoparia as possessed by *Paradoxides*. We have already referred to the probable correlation of the supragenal spines on the lateral margin of the head-shield of *Proboloides* with the parial spines of the Opisthoparia (see above).

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[1] Barrois, Pruvost, etc., *Mem. Geol. Soc. Geol. du Nord,* t. vi, ii, fasc. 2, 1920, p. 122, pl. xv, figs. 1–5.

[2] Asselberghs, *Mem. Mus. Roy. Hist. Nat. Belgique,* No. 33, 1923, p. 55.

[3] R. and E. Richter, op. cit., 1926, p. 211.

[4] Reed, *Ann. S. Afr. Mus.*, xxii, 1925, pp. 139–48.

[5] Raw, *Q.J.G.S.*, vol. lxxxi, 1925, pp. 279–85, pl. xv.

### (*h*) *Trimerocephalus* McCoy, 1849.

There is considerable confusion and diversity of usage in the name *Trimerocephalus*.

The type-species is *Tr. mastophthalmus* Reinh. Richter, which according to the Richters [1] is synonymous with *Trinucleus laevis* Münster, 1842, and this form has been re-described in detail by these authors.[2] The English trilobite which is usually referred to *Phacops* (*Trimero.*) *laevis* Münst. is considered by Thomas [3] and the Richters (op. cit., 1919, p. 134) to be distinct, and the name *Ph. trinucleus* Salter should be applied to it.

The Richters in 1923 separated off certain of the species usually assigned to *Trimerocephalus* to form a new subgenus *Dianops*, with *Ph.* (*D.*) *limbatus* Reinh. Richter as its type, mentioning *Ph. anophthalmus* Frech, *Trimero. typhlops* Gürich, and *Trimero. griffithides* R. and E. Richt. as further examples of it, and subsequently in 1926 they would remove certain other species into new subgenera, *Nephranops* and *Cryphops* (see above).

If we follow the Richters in this matter, a revision of the British species [4] usually ascribed to *Trimerocephalus* will be necessary. Perna in 1915,[5] used the name in the wider sense, including *Ph. anophthalmus* and many other species in it. Gortani's subgenera [6] of *Trimerocephalus* do not appear to have been adopted by other authors, as above mentioned, and the Richters reject them. The latter authors gave in 1923 a revised definition of *Trimerocephalus* as follows: "Saum und Saumfurche am hinteren Wangeneck entwickelt. Verschlussfurche [=subcranidial groove] tief und breit; ihre Hinterkante nicht höher als die vordere. Schwanz kurz, breit gliederarm; Rippen deutlich gespalten." In 1926 they use the name as denoting a subgenus of *Phacops* and give a full history of its usage, discussing the differences between it and their new subgenera. The genus is apparently limited to the Upper Devonian. Whether it is worthy of generic rather than of subgeneric rank is a matter of opinion, Gürich[1] and Wedekind[2] in 1911 regarding it as such, but in 1914 the latter[3] put it as a subgenus of *Phacops*, and the Richters in 1923 and 1926, and Kozlowski[4] in 1923 are of the same opinion. Most English authors agree with them in this respect. But there has been much difference of opinion as to the adequacy of the reasons for the separation of *Phacops* sens. str. from *Trimerocephalus*, and the fullest summary of their characters and differences has been given by Wedekin (op. cit., 1914, p. 40) and still more recently revised by the Richters (op. cit., 1926, pp. 126–31, 168).

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[1] R. and E. Richter, *Senckenbergiana*, Bd. v, Heft 3–4, 1923, p. 137; id., *Abh. preuss. geol. Landesanst.*, N.F., Heft 99, 1926, p. 168.

[2] *id.*, *Senckenbergiana*, Bd. i, Nr. 4, 1919, pp. 133–5, text-figs. 1*a*, *b*.

[3] Thomas, GEOL. MAG., Dec. V, Vol. VI, 1909, pp. 167–9.

[4] Thomas, op. cit., 1909, pp. 97–102, pl. iii, figs. 1–4; pp. 167–9; pp. 193–6, pl. viii, figs. 1–5.

[5] Perna, *Mem. Com. Geol. Russ*, N.S., Livr. 138, 1915, pp. 52–4, pl. i, figs. 9–18.

[6] Gortani, *Mem. Accad. Scient. Instit. Bologna*, ser. VI, t. iv, 1907, p. 229.

Taking *Phacops latifrons* Bronn, as the type of *Phacops* s. str., Wedekind gives the following characters:—Head short and broad, glabella strongly inflated, rising vertically from the front edge above the doublure. Mero- and pleuro-occipital segment clearly marked out, but lateral border usually not sharply defined. Frontal border lies below, never in front of glabella. Three glabellar furrows typically marked, the two anterior ones rudimentary, the basal (posterior) one always strong and deeply sunken, so that a basal ring is completely cut off from the glabella. Subcranidial furrow running to the posterior angles of the head-shield and sharply impressed. Doublure forming an inferiorly concave plate, strongly narrowing on each side. Pygidium with entire margin.

The Richters (1926) claim to recognize several groups of species in *Phacops* sens. str. from the Upper Devonian (see below).

Wedekind says that *Trimerocephalus* is distinguished from *Phacops* s. str. by the small or absent eyes, which are always without a palpebral lobe (augendeckel). In all other characters it corresponds completely with *Phacops*. But a striking character is that the glabella in most forms (but not all) projects as a broad triangular snout over the frontal border, which always lies under, never in front of the glabella. The angle which the anterior end of the glabella makes with the doublure is obtuse. The basal lobe is completely cut off from the glabella as in *Phacops*. The subcranidial furrow is similarly developed. The anterior branch of the facial suture cuts the margin very far forward, so that the free cheeks are small and triangular. It must be borne in mind that Wedekind includes in *Trimerocephalus* the species which the Richters have now separated off into the subgenera *Dianops*, *Nephranops*, and *Cryphops*. Gürich (op. cit., 1909, p. 162) believes that *Trimerocephalus* is more allied to the *Ph. glockeri* group (=*Phacopidella* s. str.) than to *Phacops* s. str., and in 1896 he considered that the *Trimerocephalus* group lacked homogeneity. But Kozlowski (1923, p. 29) accepts Wedekind's definition, and considers that *Denckmannites* and *Glockeria* should be included in *Phacopidella*, a view also adopted by the Richters in 1926.

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[1] Gürich, op. cit., 1909, p. 162.

[2] Wedekind, *Zeitschr. deut. geol. Gesell.*, lxiii, 1911, p. 320.

[3] Id., op. cit., 1914, p. 40.

[4] Kozlowski, op. cit., 1923, p. 36.

The latest definition of *Trimerocephalus* in its restricted sense is given thus by the Richters (op. cit., 1926, p. 171) :—" Saumfurche (= Naht) unter der Glatze stärker gekrummt als die Verschlussfurche, sich in der Mitte von ihr entfernend (*Ph.* : Parallel, nahe beieinander). Zwischen diesen Furchen bleibt also als ' Saum ' ein breiter, in der Mitte verbreiterter Schalenstreifen (*Ph.* : nur eine schmale, gleichbreite Leiste, die bereits die Vorderkante der Verschlussfurche bildet). Verschlussfurche tief und breit (*Ph.* : schmal) Ihre Hinterkante ebenso hoch oder ein wenigniedriger als die Vorderkante (*Ph.* : höher). Umschlag schmal, ins Kopfinnere geneigt, nur den Abhang der Hinterkante darstellend (*Ph.* : breit, flachliegend, vorgewölbt oder eben). Saum an der Wange entwickelt ; Saumfurche am hinteren Wangeneck durchlaufend (*Ph.* : oft nicht entwickelt). Schwanz sehr klein, kurz und breit, gliederarm ; Rippen deutlich gespalten (*Ph.* : länger, gliederreicher, Rippen oft ungespalten).

The species mentioned are *Ph.* (*Tri.*) *mastophthalmus* Reinh. Richter 1856, *Ph.* (*Tri.*) *steinachensis* R. and E. Richter, and *Ph.* (*Tri.*) *caecus* Gürich.

### (*i*) *Phacops* Emmrich, 1839.

(Subgenotype : *Ph.* (*Ph.*) *latifrons* Bronn, 1825.)

The use of the term *Phacops* in a subgeneric sense to denote one of the divisions of *Phacops* sens. extenso is fairly general, and the Richters (op. cit., 1926, p. 132) have recently defined its limits and the characteristics which distinguish it from *Trimerocephalus*, though many other palaeontologists hold different views, as their list of synonyms indicates. Their definition is as follows :—" Verschlussfurche und Saumfurche (die Naht enthaltend) an der Stirn parallel laufend, und zwar nahe beieinander bleibend. Zwischen beiden ist daher nur Platz fur ein schmales Schalenstreifchen. Dieses springt leistenartig vor und bildet die Vorderkante der Verschlussfurche. Die Hinterkante ist, von unten gesehen, höher also die vordere. Die Schale hinter der Hinterkante ist gern konvex." These authors recognize the following Upper Devonian groups in the subgenus (1) *Ph. breviceps* Barrande, 1852, and (2) *Ph. granulatus* Münst., 1840, the latter including *Ph. rana* Green.

### (*j*) *Typhloniscus* Salter, 1856.

With regard to *Typhloniscus* Clarke (1913, op. cit., p. 158) put this genus with the phacopids and considered that the type-species *T. baini* Salt.[1] from the Lower Devonian of South Africa, had the peculiar glabellar structure which prevails amongst the austral phacopids. Probably it occupies the same place in the acastid series as *Trimerocephalus* (or more probably *Dianops*) does in the phacopid series, but Kozlowski (1923, op. cit., p. 31) does not seem to be right in putting it as a subgenus of *Acaste*, and in the light of the new evidence of the head-shield we may point to its resemblance to some species of *Areia*.[1]

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[1] Lake, *Ann. S. African Museum*, vol. iv, pt. iv, 1904, p. 213, pl. xxv, figs. 8, 9. Reed, ibid., vol. xxii, 1925, p. 162.

We may doubt if the Ordovician trilobite from the Sholeshook Limestone named *Typhloniscus princeps* by the author [2] belongs even to the same genus as the South African Devonian type, for its characters, as then remarked, are decidedly Cheirurid. Probably it belongs to a new subgenus of *Cheirurus* and has nothing to do with the true *Typhloniscus*, only resembling it in being blind.

### (*k*) *Metacanthus* Hawle and Corda, 1847.

This subgeneric name has been revived by the Richters [3] for the small group of Devonian trilobites of which *Asteropyge* (*Cryphaeus*) *stellifer* (Burmeister, 1843) is the type. To this same group they would ascribe *Dalm.* (*Cryph.*) *boothi* Hall and Clarke. *Metacanthus* was founded by Hawle and Corda for trilobites like *Asteropyge*, but possessing an unequal number of free points or spines on the margin of the pygidium, an unpaired central point being present, whereas in *Asteropyge* there is no central point and the spines occur in pairs. Barrande [4] rejected the generic name, the spinose development being of doubtful value, and Hall and Clarke and practically all subsequent palaeontologists have been of opinion that the presence or absence of a medium spine is of no moment.

### (*l*) *Chasmops* McCoy, 1849.

The peculiar V-shaped lines of pits on the frontal lobe of members of *Chasmops* has been shown by Born [5] to mark the attachment of the hypostome, and a similar feature is occasionally met with in *Pterygometopus* and other genera as pointed out by Richter.[6] Warburg [7] in describing *Ch. macrourus* Sjögren, from the Leptaena Limestone, doubts if Salter's form bearing this name is identical.

### (*m*) *Pterygometopus* Schmidt, 1881.

Raw [8] in 1925 expressed the opinion that *Pterygometopus hunteri* Reed from the Ordovician of Girvan (Balclatchie Beds) was perhaps the most primitive Phacopid known, the long palpebral lobes and the hexameral segmentation of the cephalic axis resembling the Cambrian genus *Paradoxides*.

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[1] Olin, op. cit., 1906, p. 46, t. 1, figs. 10–12.

[2] Reed, GEOL. MAG., Dec. V, Vol. V, 1908, p. 433, Pl. XIV, Figs. 1–3.

[3] R. and E. Richter, op. cit., 1926, p. 225.

[4] Barrande, *Syst. Silur. Bohême*, vol. i, 1852, pp. 536, 537.

[5] Born, *Senckenbergiana*, Bd. 1, No. 5, 1919, pp. 159–71.

[6] Richter, *Palaeont. Hungarica*, vol. i, 1923, pp. 78–80.

[7] Warburg, *Bull. Geol. Instit. Upsala*, vol. xvii, 1925, p. 399, pl. xi, figs. 22–4.

[8] Raw, *Q.J.G.S.*, vol. lxxxi, 1925, p. 280.

## CLASSIFICATION.

In 1908 Gürich[1] in summarizing the Silurian and Ordovician *Phacopidae* mentions only the following four genera :—*Phacops*, *Dalmania*, *Acaste*, and *Chasmops*, without giving any subgenera. In 1909 the same author[2] quotes the four following genera as occurring in the Devonian :—*Dalmania* (with s.g. *Odontochile* = *Hausmannia*), *Cryphaeus*, *Trimerocephalus*, and *Phacops*, and he divides the *Phacopidae* into two subfamilies of which the first (*Dalmaninae*) is characterized by the lateral furrows of the glabella, being sharply marked, and the second (*Phacopinae*) by these furrows being indistinct.

Raymond in Eastman Zittel's *Textbook of Palaeontology*, 1913, p. 725, divides the *Phacopidae* into three subfamilies, the first of which (*Dalmanitinae*) contains the following genera : (*Dalmanitina*, *Dalmanites*, *Asteropyge* (= *Cryphaeus*) Green, and *Probolium* ; the second (*Phacopinae*) contains *Phacopidella* (*Acaste* Goldf.), *Phacops* and *Trimerocephalus* ; the third (*Pterygometopinae*) contains *Pterygometopus*, *Chasmops*, and *Monorakos*. He thus adopts the three subfamilies which the author suggested in 1905, and also uses several of his names, but he does not mention the Austral generic types, and unfortunately figures *Phacops downingiae* as the representative of *Phacopidella*, falling into the author's error of 1905.

Wedekind[3] gave in 1911 a most useful review of the characters of the *Phacopidae*, using the family name in the restricted sense (= *Phacopinae* Raymond). He attached special importance to the characters of the occipital segment and to the basal furrows on the glabella, which may unite across the base of the glabella, forming a complete intercalary (pre-occipital) ring or remain separate, forming a pair of more or less independent basal lobes. The following four genera were enumerated :—

| | | | |
|---|---|---|---|
| Genus | *Phacops.* | Subgenus | *Phacops* s. str. |
| | | ,, | *Trimerocephalus.* |
| ,, | *Reedia.* | | |
| ,, | *Glockeria.* | ,, | *Glockeria* s. str. |
| | | ,, | *Denckmannia.* |
| ,, | *Pterygometopus.* | ,, | *Pterygometopus* s. str. |
| | | ,, | *Pterygometopidella.* |

In 1914 the following fuller classification of the *Phacopidae* in its broad sense was proposed by Wedekind[4] :—

Subfamily DALMANITINAE Reed.
Genus *Dalmanites* Barrande.
Subgenus *Dalmanitina* Reed.
,, *Hausmannia* Hall and Clarke.

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[1] Gürich, *Leitfossilien, I*, Kambrium and Silur., 1908, p. 71.
[2] Ibid., II, Devon, 1909, pp. 157–68.
[3] Wedekind, *Zeitschr. deut. geol. Gesell.*, Bd. lxiii, 1911, pp. 317–36.
[4] Wedekind, *Abh. preuss. geol. Landesanst.*, N.F., Heft 69, 1914, pp. 25–74.

Genus *Odontocephalus* Conrad.
Genus *Glockeria* Wedekind.
    Subgenus *Glockeria* sens. str. Wedekind.
    „ *Denckmannites* Wedekind.
Subfamily Phacopidinae Reed.
Genus *Acaste* Goldfuss.
    Subgenus *Acaste* (sens. str.) Goldfuss.
    „ *Cryphaeus* Emmrich.
Genus *Phacops* Emmrich.
    Subgenus *Phacops* (sens. str.) Emmrich.
    „ *Trimerocephalus* McCoy.
    „ *Reedia* Wedekind.

This requires considerable enlargement and correction in the light of later research. Moreover, Wedekind does not take account of the *Phacopidae* of the southern hemisphere which differ considerably in Devonian times from those of the northern. Clarke[1] by his researches into the South American faunas has established this fact, and the South African trilobites afford the same testimony. In consequence of this evidence, and the necessity for new terms, Clarke introduced a completely different grouping and classification, establishing many new genera or subgenera of importance, which seem to be mostly limited to the austral province. Thus he was led to unite under the name *Phacopina* all those in which the anterior and middle glabellar furrows are faint or obsolete and the pygidium relatively long but having a simple entire margin. All the others were united by him with one group under the name *Mesembria*, comprising two subdivisions, *Metacryphaeus* and *Anchiopella*, as above described. The former consists of species with a glabella uniformly depressed, with lateral furrows feeble and a pygidium generally provided with marginal denticles; the latter comprises the species with swollen glabella, lateral lobes more or less coalescent and pygidium with entire margin. In the subdivision *Metacryphaeus* the genera *Calmonia*, *Pennaia*, and *Proboloides* were placed, occupying a place analogous to that of *Cryphaeus*, *Cryphina*, and *Probolium* in *Dalmanites*, according to Kozlowski, while *Anchiopella* corresponds to the group *Synphoria* in *Dalmanites*. This convergence of structure or homoeomorphy is pointed out especially by Kozlowski (1923, pp. 31, 33). A parallel development in the austral and boreal provinces appears to have taken place, representative subgenera having independently arisen.

One of the fullest discussions lately published, with respect to the classification of the *Phacopidae* and the validity of the several genera and subgenera has been given by Kozlowski (op. cit., 1923, pp. 32–6), in which he takes account of both the boreal and austral types. He distinguishes four genera in the family, viz. *Acaste*, *Pterygometopus*, *Dalmanites*, and *Phacops*, and he distributes the subgenera amongst them as follows:—

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[1] Clarke, op. cit., 1913, pp. 101–59.

| Genus *Acaste.* | Subgenera : |
|---|---|
| | *Acaste* sens. str. |
| | *Phacopina.* |
| | *Anchiopella.* |
| | *Pennaia.* |
| | *Calmonia.* |
| | *Proboloides.* |
| | *Typhloniscus.* |
| Genus *Pterygometopus.* | *Pterygometopus* s. str. |
| | *Chasmops.* |
| | *Monorakos* (= *Monorachus*). |
| Genus *Dalmanites.* | *Dalmanites* s. str. (= *Hausmannia*). |
| | *Dalmanitina.* |
| | *Cryphaeus.* |
| | *Cryphina.* |
| | *Coronura.* |
| | *Odontocephalus.* |
| | *Corycephalus.* |
| Genus *Phacops.* | *Phacopidella.* |
| | *Phacops* s. str. |
| | *Bouleia.* |
| | *Dereimsia.* |
| | *Trimerocephalus.* |

The true *Phacops.* s. str. seems very rare in the austral fauna of Devonian age. Thomas[1] describes one from Argentina as *Ph. argentinus* n.sp., and Kozlowski[2] one from Bolivia as *Ph. salteri* sp. nov., to which he refers Salters[3] *Ph. latifrons* from the High Andes, and Groth's[4] *Ph. rana* from Peru.

With Kozlowski's scheme the author is in partial agreement, but he is doubtful about the re-establishment of *Acaste* (= *Acastina* nom. prop.) as a generic group, and the assemblage of subgenera under this name which Kozlowski gives is somewhat heterogeneous. In 1925 the author[5] used the following classification and employed the following names in a slightly different generic or subgeneric sense when describing the Devonian trilobites from South Africa.

Genus *Dalmanites*
Subgenera *Anchiopella.*
,, *Corycephalus*
,, *Hausmannia.*
,, *Proboloides.*
,, *Acastella.*
,, *Cryphaeus.*

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[1] Thomas, *Zeitschr. deut. geol. Gesell.*, lvii, 1905, p. 246, t. xi, figs. 8, 9*a*, *b*.

[2] Kozlowski, op. cit., 1923, p. 54, pl. vi, figs. 1–6.

[3] Salter, *Q.J.G.S.*, xviii, 1861, p. 65, pl. iv, fig. 8.

[4] Groth, *Bull. Soc. Geol. France*, ser. iv, vol. xii, 1912, p. 607, pl. xix, figs. 2, 2*a*.

[5] Reed, *Ann. S. Afr. Mus.*, xxii, 1925, pp. 122–63.

Genus *Phacops.*
  Subgenera *Calmonia.*
    ,, *Pennaia.*
    ,, *Phacopina.*
    ,, *Bouleia.*
Genus *Typhloniscus.*

Amongst the foregoing the occurrence in South Africa of the boreal types *Corycephalus*, *Bouleia*, and *Acastella* is somewhat doubtful, the evidence being poor; and the above list naturally does not claim to include all the members of the *Phacopidae.*

If we attempt a complete classification of all the genera and subgenera of the *Phacopidae*, the following scheme seems to correspond most nearly with our present knowledge of the group :—

Subfamily DALMANITINAE.
  Genus *Dalmanites*
    Subgenera *Dalmanites* s. str. (= *Hausmannia*).
      ,, *Dalmanitina* s. str.
      ,, *Cryphaeus* (= *Asteropyge*).
      ,, ? *Comura.*
      ,, ? *Metacanthus.*
      ,, *Cryphina.*
      ,, *Coronura.*
      ,, *Odontocephalus.*
      ,, *Corycephalus.*
      ,, *Anchiopella.*
      ,, *Probolium.*
      ,, *Acastella.*
      ,, *Proboloides.*
      ,, *Synphoria.*

Subfamily PHACOPINAE.
  Genus *Phacops.*
    Subgenera *Phacops* sens. str.
      ,, *Reedops.*
      ,, *Phacopina.*
      ,, *Phacopidella* sens. str.
      ,, *Trimerocephalus* sens. str.
      ,, *Dianops.*
      ,, *Nephranops.*
      ,, *Cryphops.*
      ,, *Portlockia.*
      ,, ? *Denckmannites.*
      ,, *Bouleia.*
      ,, *Dereimsia.*
      ,, *Acaste* sens. str. (=*Acastina* nom. prop.)
      ,, *Calmonia.*
      ,, *Pennaia.*

Subfamily PTERYGOMETOPINAE.
Genus *Pterygometopus.*
,, *Chasmops.*
,, *Monorakos.*
,, *? Josephulus.*
Incertae sedis
Genus *Typhloniscus.*

The names in the foregoing list to which a query is attached hardly seem to indicate well established subgenera, the value of the characters on which they are founded being doubtful.

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# Some Variations in *Ulocrinus* and *Hydreionocrinus.*

By JAMES WRIGHT, F.G.S.

## INTRODUCTION.

IN furtherance of an intention expressed in a former paper (GEOL. MAG., Vol. LXIII, 1926, p. 143), I propose, in this communication, to give some statistics of the anal variations in 542 cups, all of which are referred to the genus *Ulocrinus*. Additional details are also given of similar variations in 130 cups referred to *Hydreionocrinus*. Fifty of the latter have already been dealt with elsewhere (*Trans. Geol. Soc. Glasgow*, vol. xvi, pt. iii, 1917–18, p. 383), but to complete the survey of the anal area in the four groups of cups for the present, it is thought advisable to include them here. The classification here adopted is the same as that given for *Eupachycrinus calyx* and *Zeacrinus konincki*, namely :—

Primitive Type.—All forms in which anal X, at its lower end, has more or less wide contact with post. B, and lower end of RA has a similar connexion with right post. B.

Primitive Type A.—As above, but with lower end of RA detached from right post. B.

Advanced Type.—Where the RA has a direct connexion with left post. R, and X is entirely separated from post. B.

Advanced Type A.—Similar to above, but with lower end of RA detached from right post. B.

## ULOCRINUS.

The cups referred to this genus are all from localities in the Scottish Carboniferous Limestone Series, but unlike the case of *Eupachycrinus calyx* and *Zeacrinus konincki*, which occur in the same stratigraphical horizon, we are here dealing with groups of specimens from different platforms. The chief purpose of my examination being to trace out the anal variations in the cups, I do not attempt here to deal specially with the zonal value of these fossils. At the same time, this aspect of the subject has claimed, and still claims, some attention ; but so far as I can at present see with the material at command, which consists of cups only and not crowns, the ultimate result does not look promising. It is true that if one group of specimens is compared with another, e.g those from a lower with a higher horizon, they vary considerably in their general aspect. This, however, is mainly due to the lithological characters of the sediments in which they occur, no two of which are precisely alike. Then, as regards the shape of the cups, which is the only criterion of value in this direction, it is not always an easy matter to arrange the specimens in a satisfactory manner. Apart from certain main features which may be paralleled in cups from all horizons, there are, from some shale beds, many cups which are somewhat crushed or distorted, so that in such cases it is difficult to determine their true contour.

As to the aspect of the specimens as a whole, one might state as a general rule that the cups from the more shaly and less calcareous beds are on the average comparatively small in size, with smooth, occasionally glossy plates. Those from more hard calcareous beds, i.e. shaly layers usually overlying and in direct contact with a thick limestone, attain to a larger size and as a whole have plates of somewhat coarser texture. The cups from localities 1, 7, 12, and 16 belong to the former category, and from localities 3, 4, 5, and 6 to the latter. Some notes on localities are given later, but the following remarks are applicable to the specimens in general.

### LOCALITIES AND NUMBER OF CUPS.

| | | |
|---|---|---|
| *West Fife.* | | |
| 1. | 2nd Abden Limestone (No. 2 Limestone), Kirkcaldy-Kinghorn Coast Section | 4 |
| 2. | “ Bottom Bed,” Seafield Tower Limestone, Kirkcaldy-Kinghorn Coast Section | 43 |
| 3. | Seafield Tower Limestone (No. 3 Limestone), Kirkcaldy-Kinghorn Coast Section | 114 |
| 4. | Invertiel | 143 |
| 5. | Roscobie | 20 |
| 6. | Duloch | 44 |
| 7. | No. 4 Limestone, Kirkcaldy-Kinghorn Coast Section | 47 |
| 8. | Stenton, Thornton (Levenseat Limestone) | 2 |
| *Central Fife.* | | |
| 9. | Cults | 17 |
| *East Fife.* | | |
| 10. | “ White Limestone,” St. Monans Coast Section | 3 |
| 11. | Zone 33, ,, ,, | 3 |
| 12. | Zone 19, ,, ,, | 79 |
| *West and South Scotland.* | | |
| 13. | Gateside, Beith, Ayrshire | 2 |
| 14. | Dockra, Beith, Ayrshire | 8 |
| 15. | Brockley, Lanarkshire | 2 |
| 16. | Penton Linns, Dumfriesshire | 11 |
| | Total | 542 |

| | *Primitive Type.* | *Primitive Type A.* | *Advanced Type.* | *Advanced Type A.* |
|---|---|---|---|---|
| 3. Seafield Tower Limestone | 8 | 0 | 105 | 1 |
| 4. Invertiel . . . | 37 | 0 | 105 | 2 |
| 5. Roscobie . . . | 6 | 0 | 12 | 2 |
| 6. Duloch . . . | 3 | 0 | 40 | 1 |
| 2. "Bottom Bed," Seafield | 0 | 0 | 41 | 2 |
| All other localities. . | 0 | 0 | 177 | 0 |
| | 54 | 0 | 480 | 8 |

In former years cups of the types under discussion were in Scotland referred to de Koninck's species, *Hydreionocrinus* ? *globularis* (1858, *Bull. Acad. Roy. Bruxelles*, ser. II, vol. iv, p. 93, pl.-figs. 6, 7; *Geologist*, vol. i, p. 179), and occasionally to *Poteriocrinus nuciformis* MacCoy (*Ann. Mag. Nat. Hist.*, April, 1849). (See *Geological Survey Memoirs*, etc.) In more recent years Dr. Bather has referred the cups to *Ulocrinus* (Miller and Gurley, 1890), and in an interesting paper communicated to the Geological Society of Glasgow in February, 1917, and published in the *Transactions* in December of the same year, he discusses the genus with special reference to the British specimens. Among other matters of interest he gives a classification of the cups he has handled (most of which are in the British Museum, including a good number from Fife), as follows:—

*Ulocrinus nuciformis* MacCoy.
conical form ⎫
goblet form ⎭ Sub-conical shape.
*Ulocrinus globularis* de Kon.
spheroidal form ⎫
elongate form ⎭ Globular shape.

One observes that in this classification nearly all the Scottish specimens are comprised under *U. globularis*, elongate form, the remainder, which are few in number, coming under *U. nuciformis*, goblet form, and a cup of the latter type found at Corrieburn by Mr. James Begg is described in the paper. Dr. Bather further thinks the name *U. globularis* will probably in future be displaced by *U. bockschii* Geinitz, which has priority, having been published in 1848, the species itself being apparently indistinguishable from *U. globularis*.

In classifying the cups as to shape, one may, broadly speaking, group a large number under *U. globularis*, and sort them out according to Dr. Bather's plan as the spheroidal and elongate forms, but here it is not always possible to draw a hard and fast line, since there are many intergradations between them. In specimens like Figs. 1, 3, 50, 51, which are from the Seafield Tower Limestone, at Seafield and Invertiel, the IBB circlet is very low with convex contour, the height of the cups is about the same or less than the diameter, and such specimens may be termed spheroidal and taken as the extreme range of the shape. A specimen like Fig. 26, which is from Zone 19, St. Monans, is typical of a shape which occurs in most of the shale deposits. This also might be termed spheroidal, and can be matched in numbers in the Seafield Tower Limestone. The more elongate shapes, like Figs. 18, 19, 22, from the Seafield Tower Limestone; Fig. 23 from Stenton; Figs. 25, 28, from "Bottom Bed", Seafield; and Figs. 27, 29, from Zone 19, St. Monans, are typical of most localities. Figs. 42 and 44 are elongate forms from No. 4 Limestone, Seafield. For their height these cups have rather lower IBB circlet than usual, but they do not otherwise differ greatly from such a form as Fig. 43, which is from Invertiel. Shapes like these are common to all deposits. It is noteworthy that in the Seafield Tower Limestone and on this horizon only, at Seafield and Invertiel, we meet with a series of forms in which the IBB circlet tends to become higher with almost straight or slightly concave sides, the top of the cup is less constricted, Figs. 30, 31, 32, and the cup generally is more elongated in outline and culminates in a few shapes like Figs. 33, 35, 36.

I have not had the advantage of seeing the types of *U. nuciformis* as found in England, but judging from the figures given by MacCoy (*Palaeo. Foss.*, pl. iii D, figs. 4, 4*a*) and by Dr. Bather (*Trans. Geol. Soc. Glasgow*, vol. xvi, pt. ii, 1916–17, p. 208, fig. 1), I suspect that specimens of the nature of Figs. 30 to 37 might be classed under that name. Meanwhile, in the absence of other criteria, I am inclined to look upon all these shapes simply as individual or local variations of *U. globularis*, or if that name has to be dropped, *U. bockshii*

The anal area in all the specimens presents little difficulty, unless it be that the suture lines are sometimes hard to detect owing to the smooth character of many of the cups. While one notes considerable differences in size and shape of the RA, this plate in the advanced type occupies the dominant position in the anal region, since at its lower end it usually has a more or less wide junction with the right post. B and on the left a similar connexion with left post. R. There are a few modifications to be noted later, but as may be gathered from the totals given above this character remains constant for the great majority of the cups, Figs. 14 to 51. Apart from these, and confined to the Seafield Tower Limestone and its inland equivalents, we have a small group with a primitive type of anal area, and here also we find a great range of shape. Some are quite globular, like Figs. 1, 3, others elongated like Figs. 6, 11, and 12. The most noticeable difference between these cups and those exhibiting the more advanced type of anal area is the greater breadth of the cups at the top, due, of course, to the incorporation of the three comparatively equal anal plates and the meeting of anal X with post. B. Occasionally, however, one observes an example where the top of the cup, round the rim of the radial circlet, is more constricted, Fig. 8, and such a form has its counterpart in the advanced type in such a specimen as Fig. 39*a*. Although in this group may be observed many differences in size, etc., of the anal plates, I have not yet come across one in which the lower end of RA is detached from right post. B. We may, however, look upon Figs. 14, 15, and 16 as examples of transition forms in the advanced type, since the left shoulder of RA is very narrow in its connexion with left post. R. Fig. 13 is somewhat abnormal, in that two plates are shown in the position usually occupied by RA.

In measuring some of the cups one notices a considerable bulge on the anal side. In all cases the diameter measurements are taken across the cups from left to right post. basals at the widest part, but in cups in which the bulge is most pronounced the difference, if measured from posterior to anterior, amounts to 1 mm. and over. Two cases might be mentioned ; Fig. 45, the diameter across being 12·9 and measured from post. to ant. 14·2 ; and Fig. 49, diameter across 15·3, and from post. to ant. 16 mm. Occasionally one finds the reverse state of matters, when the greatest diameter is from left to right, but generally speaking the cups are fairly uniform in this respect.

A notable feature in some cups is the swollen character of the basals, Figs. 19 and 21, which, in conjunction with the constriction of the radial circlet, as in Fig. 21, gives the cup a peculiar aspect. Another feature in some cups of the more globular shapes, Figs. 26, 51, is the relatively small height of the RR as contrasted with the elongated varieties in which the RR are narrower and higher plates.

As may be noted from the figures, the RA varies considerably in shape. In the advanced type it is usually surmounted by two plates, anal X and r t, but it is quite common to find specimens with only one plate, anal X, on top, Figs. 28, 28*a*, 40, 42, 46. When this occurs X generally occupies all the space between left and right post. radials. Occasionally, however, we find a few forms like Figs. 41, 45, 49, in which r t is wedged in between the top right corner of right post. R and anal X. Then there are forms, common to various horizons, like Figs. 20, 39*a*, and 48, where the top of RA extends up to the line of the radial circlet, and occasionally beyond, Fig. 44. In size the RA is no less variable. We find it in some forms very large as in Fig. 49, in others comparatively small, as in Figs. 42, 43. In Fig. 38 it is unusually large, but here the entire cup is abnormal, the IBB and B circlets consisting only of four plates each and left post. R linking up with left post. IBB.

Among the cups, it is not uncommon to find instances of the narrowing of the lower end of RA as indicated by Figs. 24 and 47, but excepting in the eight cases to be immediately mentioned, complete detachment is never seen. In the cups shown on Figs. 52, 53, 54, 55, 55*a*, 56, and 57, the lower end of RA is entirely separated from right post. B, and in Fig. 57 has become very small. These variations, though small in number, remind us of similar variations at the extreme end of the *Eupachycrinus* and *Zeacrinus* series.

(This particular type of anal structure is not unlike that given for *Ulocrinus buttsi* in Lankester's *Zoology*, vol. iii, p. 122.) So far we have not met with any specimens in which RA is entirely eliminated from the calyx.

## LOCALITIES.

Unless otherwise stated the first line of figures gives the height of cup, the second the diameter or widest part, the third the width at top, and fourth the height of IBB circlet.

1. *2nd Abden Limestone.*

This is the lowest horizon from which I have collected cups of *Ulocrinus.* It lies about 100 feet below the Seafield Tower Limestone, from which it is separated by a group of sandstones and shaly beds. From the topmost layer of the shales overlying the limestone four cups only have been found. Two of these are somewhat crushed, the other two, however, being finely preserved. These latter tend to be more globular than elongate and measure as follows:—

| *Height.* | *Greatest Width.* | *Width at top.* | *Height of IBB.* |
|---|---|---|---|
| 8·7 | 9·4 | 5·9 | 1·4 |
| 6·6 | 6·4 | 4·3 | 1·0 |

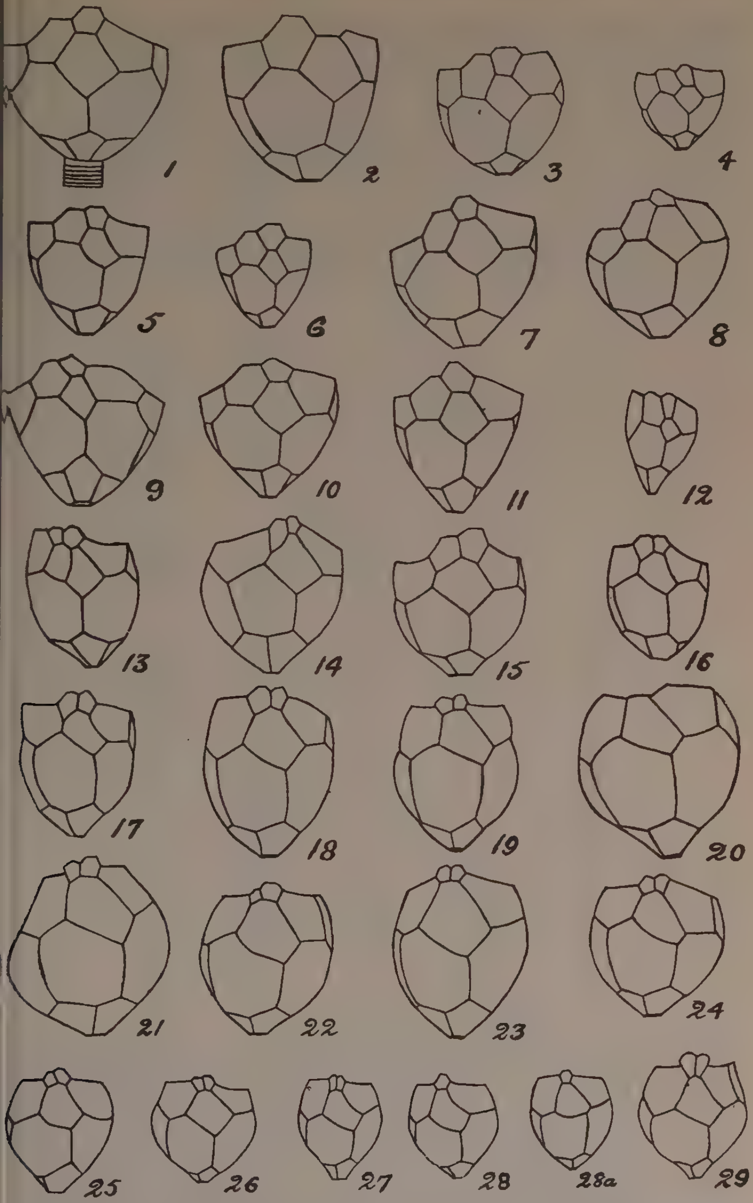
2. "*Bottom Bed,*" *Seafield Tower Limestone.*

Directly under the Seafield Tower Limestone is a group of black shales about 4 feet thick, which are distinctly barren in fossils except in the layer immediately below the limestone. This layer has yielded a fair number of cups of *Ulocrinus*, the total so far being forty-three. Twenty-three of these may be classed as elongate, Figs. 25, 28, the remainder being spheroidal, although there is the usual diversity in each group. All have smooth or polished surfaces, and the anal area in all, with exception of two specimens, is of the usual advanced type. In the two exceptions, one of which is shown on Fig. 55*a*, the anal area is of the advanced A type. Both specimens are remarkably alike in that the top of RA extends well out beyond the radial circlet. In the other specimens of the more usual advanced type there are several which show the top of RA in this position, in others again the structure shown is similar to that of Fig. 28, where RA is surmounted by a single plate. Measurements of six typical cups:—

| | | | | |
|---|---|---|---|---|
| Elongate form | 13·2 | 11·4 | 7·9 | 2·8 |
| | 10·9 | 10·9 | 7·0 | 2·3 |
| | 10·0 | 8·8 | 6·9 | 2·1 |
| Spheroidal form | 10·5 | 10·9 | 8·3 | 2·0 |
| | 10·2 | 10·4 | 7·4 | 2·0 |
| | 8·1 | 8·8 | 6·3 | 1·8 |

3, 4, 5, *and* 6. *Seafield Tower Limestone, Invertiel, Roscobie, Duloch.*

These localities may be taken together, since they all represent the same stratigraphical horizon. At Roscobie and Duloch the cups were collected from the calcareous shales and impure limestone bands directly above the limestone and at Invertiel and the Seafield Tower Limestone from a similar position above the limestone on the horizon which I have called No. 1 Bed (*Trans. Edin. Geol. Soc.*, vol. x, pt. i, 1912, pp. 49–60). The table on p. 354 gives the total of cups from this bed, and there is no doubt we have here the most interesting series from the evolutionary point of view. As may be observed, while the great majority of the specimens show the usual advanced type of anal area, it is on this horizon only that we find the group with the primitive type of anal structure. Here also we find the other six cups, in which lower end of RA has become detached from right post. B, Figs. 52–7. As already indicated, the cups as a whole vary greatly in shape and size, the



Figs. 1–29.—*Ulocrinus globularis.* 1–13, No. 1 bed, Invertiel; 14, 15, Roscobie; 16–18, No. 1 bed, Invertiel; 19, Duloch; 20–2, No. 1 bed, Invertiel; 23, Stenton; 24, No. 1 bed, Invertiel; 25, 28, 28*a*, "Bottom Bed," Seafield; 26, 27, 29, Zone 19, St. Monans. $\frac{3}{2}$ natural size.

smallest I have measured being less than 5 mm. in height and the largest over 15 mm. The variety of shape is most noticeable in the series from Invertiel and Seafield, these localities having, of course, yielded the largest number of cups. Some indications of the shapes are shown on Figs. 1 to 57, and have already been mentioned. It may only be repeated that between spheroidal forms like Figs. 48, 50, 51, and elongate like Figs. 16, 18, there are intermediate shapes which are comparable with similar shapes from other horizons, the chief difference being that the Seafield Tower cups are usually larger than the others. It is, however, on this horizon exclusively that we find the attenuated varieties like Figs. 33–7. The number of such specimens is not large, being limited in the case of Figs. 34–6 to ten cups. Among the primitive forms there are also many gradations in shape, and such forms may be paralleled among the cups of advanced type. Some measurements are appended.

*Primitive Type.*

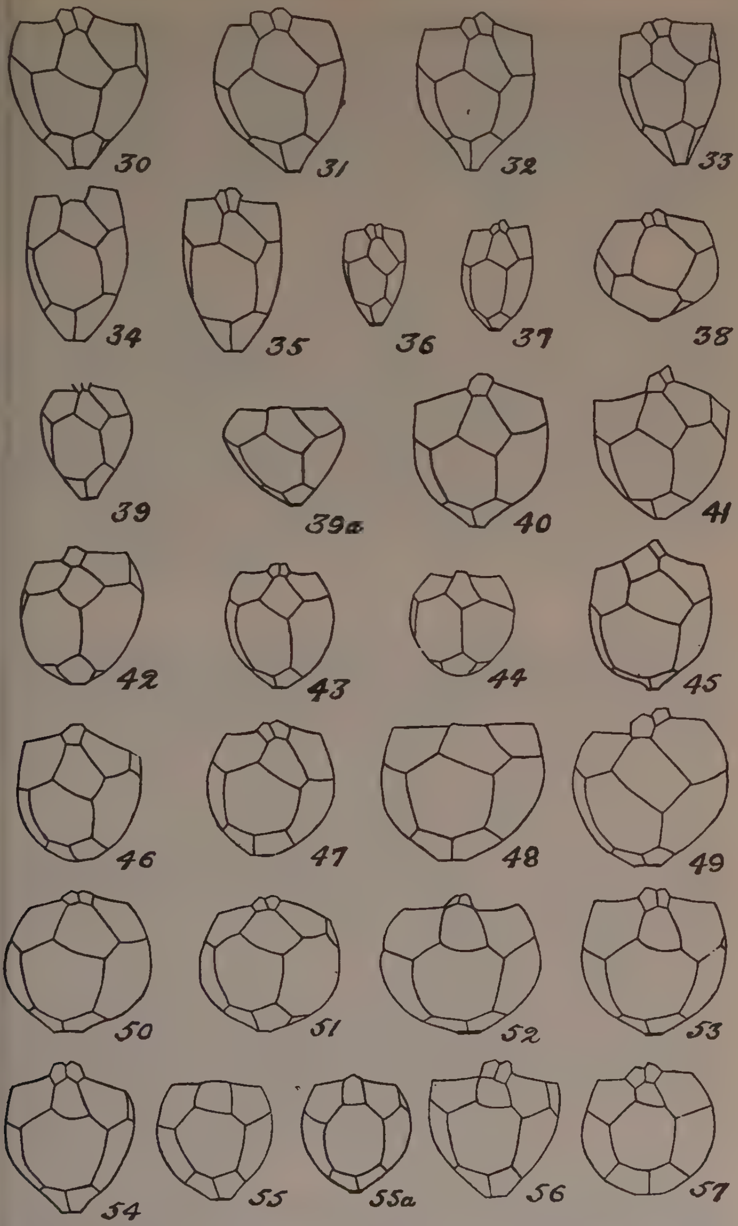
| *Figs.* | *Height.* | *Width at top.* | *Column facet.* | *Height of IBB.* |
|---|---|---|---|---|
| 1. | 12·2 | 15·5 | 2·8 | 1·8 |
| 2. | 15·0 | 15·1 | 2·9 | 2·7 |
| 8. | 13·6 | 15·4 | 2·7 | 2·8 |
| 11. | 13·7 | 13·2 | 2·8 | 3·4 |
| 12. | 9·6 | 7·8 | 1·5 | 3·1 |

*Advanced Type.*

| *Figs.* | *Height.* | *Diameter.* | *Width at top.* | *Height of IBB.* |
|---|---|---|---|---|
| 20. | 15·4 | 15·7 | 6·4 | 2·5 |
| 21. | 15·1 | 15·3 | 5·9 | 2·6 |
| 19. | 15·1 | 13·2 | 9·9 | 3·0 |
| 30. | 14·6 | 12·1 | 9·9 | 3·0 |
| 18. | 14·6 | 12·4 | 10·3 | 3·1 |
| 17. | 12·4 | 11·5 | 9·0 | 2·2 |
| 24. | 12·1 | 12·3 | 8·5 | 2·2 |
| 49. | 15·4 | 15·3 | 10·3 | 1·5 |
| 32. | 14·6 | 12·0 | 9·6 | 3·3 |
| 33. | 14·6 | 10·0 | 6·9 | 4·1 |
| 58. | 14·6 | 15·5 | 11·9 | 1·7 |
| 34. | 14·5 | 10·0 | 6·9 | 4·1 |
| 47. | 14·2 | 15·8 | 11·7 | 2·0 |
| 45. | 13·9 | 12·9 | 9·4 | 2·0 |
| 52. | 13·0 | 15·5 | 11·2 | 1·4 |
| 40. | 12·9 | 12·9 | 10·9 | 2·0 |
| 54. | 12·5 | 12·5 | 9·9 | 2·4 |
| 51. | 12·3 | 12·9 | 8·4 | 1·7 |
| 55. | 11·5 | 11·6 | 8·9 | 2·3 |
| 39. | 9·9 | 11·4 | 9·8 | 2·2 |

### 7. *No. 4 Limestone, Seafield Tower, Fife.*

This bed is the highest on the Kirkcaldy-Kinghorn shore section from which I have collected cups of *Ulocrinus*. It lies a little over 50 feet above the Seafield Tower Limestone, from which it is separated by a pink false-bedded sandstone, fireclay, and coal. The coal, about 3 feet thick, is very rarely seen, but it was rather extensively quarried during the recent coal stoppage and was then well exposed. It directly underlies a group of dark shales, in the centre of which are two rather persistent limy bands a few inches in thickness. This group I have termed a limestone, since it is highly fossiliferous throughout, and possibly represents a limestone elsewhere. (*Trans. Edin. Geol. Soc.*, vol. xi, pt. iii, 1925, p. 275.) Throughout the shales cups of *Ulocrinus* occur and appear to be dispersed more commonly in the lower half of the bed. Associated with these, but far less common, are cups of the rare



Figs. 30–57.—*Ulocrinus globularis*. 30–2, 34, 36, 37, 40, 41, 43, 45–51, 54, 56, No. 1 bed, Invertiel; 38, Cults; 33, 35, 39, 39*a*, 53, Seafield Tower Limestone, Seafield; 42, 44, No. 4 Limestone, Seafield; 52, 57, Roscobie; 55, Duloch; 55*a*, "Bottom Bed," Seafield. $\frac{3}{2}$ natural size.

*Tribrachiocrinus*, belonging probably to a new species (*Trans. Geol. Soc. Glasgow*, vol. xvi, pt. iii, 1917–18, p. 387). Unfortunately the cups of *Ulocrinus* from this horizon are nearly all somewhat crushed and it is not easy to discriminate between them as to shape. They appear to be all of elongate form, with very low IBB circlet, and all have the advanced type of anal area. The bed here being mainly a shale deposit, the cups have smooth plates with glossy surfaces. In some there is a tendency, as in the group from "Bottom Bed", for the top of RA to project beyond the line of the radial circlet (Fig. 44), also a few with one anal plate only on top of RA (Fig. 42). Measurements of two best preserved cups :—

| | | | | |
|---|---|---|---|---|
| Fig. 42 | 13·2 | 12·3 | 8·1 | 2·3 |
| Fig. 44 | 11·6 | 11·4 | 9·2 | 1·8 |

9. *Stenton, Fife.*

The limestone at this locality is correlated by the Geological Survey (Memoir on Central and Western Fife and Kinross, p. 145, 1900) with the Levenseat Limestone, which is exposed on the shore east of Kirkcaldy harbour, and occurs on a position over 2,000 feet above the Seafield Tower Limestone. It is the topmost limestone in the Carboniferous Limestone Series, and is accordingly the highest horizon from which I have collected cups of *Ulocrinus*. At Stenton the bed was formerly worked, but has been abandoned for many years. From the debris of the old quarry workings I obtained over twenty years ago, two cups, one of which is shown on Fig. 23. These cups are of good size, elongate in form, but they have nothing specially characteristic to distinguish them from others of the group from lower horizons. Dimensions are :—

| | | | | |
|---|---|---|---|---|
| Fig. 23 | 15·2 | 13·4 | 9·9 | 3·0 |
| | 14·7 | 13·5 | 10·8 | 2·9 |

9. *Cults, Fife.*

From shales above the limestone at this locality I have 17 cups. They are somewhat variable, tending on the whole to be spheroidal. They have low IBB circlet and several with top of RA in line with R circlet. Here occurs the abnormal specimen shown on Fig. 38. Dimensions of 2 well-preserved cups :—

| | | | |
|---|---|---|---|
| 11·4 | 9·9 | 6·5 | 2·6 |
| 9·0 | 9·0 | 5·0 | 2·0 |

10. "*White Limestone,*" *St. Monans Section.*

Three cups. The specimens from this bed are somewhat crushed. They occur in the shales above the limestone in association with a crinoid fauna consisting largely of a species of *Hydreionocrinus*, the cups and crowns of which will be referred to later. The cups of *Ulocrinus* are here too badly squeezed for accurate measurement, but the anal area is in all of the advanced type and the form seems to be elongate.

11. *Zone* 33, *St. Monans Section.*

Four cups. I am grouping these cups under *Ulocrinus* at present. In 1912 I submitted one of the specimens to Dr. Bather, who was at that time inclined to place it under *Bursacrinus* or *Delocrinus* (*Trans. Edin. Geol. Soc.*, vol. x, 1912, pp. 132–47). The cups are rather smaller than usual, but I have examined them carefully and so far as the anal area is concerned they do not differ much from such a specimen as that shown on Fig. 28*a*. I therefore place them under *Ulocrinus* meantime. Dimensions of best preserved cup :—

| | | | |
|---|---|---|---|
| 6·6 | 6·1 | 4·9 | 1·2 |

12. *Zone* 19, *St. Monans Section.*

Seventy-nine cups. These cups and the deposit in which they occur have been noticed elsewhere (*Trans. Edin. Geol. Soc.*, vol. x, 1912, pp. 132–47). The cups might be grouped as elongate, Figs. 27, 29, and spheroidal, Fig. 26, but between such forms there are many gradations. In some of the elongate

The RR are high narrow plates, and in the spheroidal as in Fig. 26 very low. This, as in the case of No. 4 Limestone at Seafield, is mainly a shale deposit and is of interest because, like that bed, a coal seam directly underlies the shales which also are characterized by a marine fauna throughout. This horizon is also of interest, since it is correlated by Professor MacNair with No. 4 Limestone at Seafield (*Proc. Roy. Soc. Edin.*, vol. xxxvii, 1917, p. 305). In this connexion it may be of some significance that both beds are characterized by the occurrence of *Ulocrinus* in large numbers. The cups of *Ulocrinus* are dispersed here throughout the shales as well as in a hard cement stone band which occupies a position about the centre of the group. The cups are of average size for a shale deposit, the measurements of three typical forms being as follows :—

| | | | | |
|---|---|---|---|---|
| Fig. 26 | 9·9 | 10·2 | 7·5 | 1·6 |
| Fig. 27 | 9·5 | 8·9 | 6·1 | 2·2 |
| Fig. 29 | 11·2 | 9·8 | 7·0 | 2·6 |

### 13. *Gateside, Beith, Ayrshire.*

Two cups. Elongate form.

| | | | |
|---|---|---|---|
| 10·5 | 9·5 | 5·5 | 2·4 |
| 8·7 | 8·7 | 4·6 | 1·6 |

### 14. *Dockra, Beith, Ayrshire.*

Eight cups. Elongate form. Dimensions of two well preserved specimens :—

| | | | |
|---|---|---|---|
| 9·4 | 9·0 | 6·0 | 2·0 |
| 7·0 | 7·0 | 3·5 | 1·7 |

### 15. *Brockley, Lanarkshire.*

Two cups. Elongate form.

| | | | |
|---|---|---|---|
| 11·0 | 10·3 | 8·1 | 2·5 |
| 9·4 | 9·0 | 6·4 | 2·2 |

### 16. *Penton Linns, Dumfriesshire.*

Eleven cups. Most of these are slightly crushed so that it is difficult to determine their contour. All have very low IBB circlet and, with the exception of one, the RR are low in height. The exception is a cup with extremely swollen basal plates and greatly constricted radial circlet, not unlike Fig. 21, which is from Invertiel. The radials in the Penton specimen are almost double the height of similar plates in the other cups from this locality and are relatively narrower. All have the usual advanced type of anal area.

## Conclusion.

In this examination some of the more interesting points which have emerged are : (1) in the great majority of the cups the anal area, in its main outlines, conforms to the advanced type of anal structure already associated with the figured species, *U. globularis* or *U. nuciformis* ; (2) in the comparatively small number which deviate from that structure, or in which is shown the greatest diversity of shape and size, all the specimens occur on one particular horizon, namely the Seafield Tower Limestone or its equivalents inland (the two cups like Figs. 55*a* which occur in " Bottom Bed ", Seafield, are the only examples of Advanced A type from a somewhat lower position. They appear in the shale directly under the limestone, and not above as in the group from the Seafield Tower Limestone proper. We may, however, regard the " Bottom Bed " as part of that limestone, since it clearly indicates the beginning of the great marine period which resulted in the formation of the thick limestone and overlying calcareous shale and limestone bands); (4) as far as the cups can tell us, *U. globularis*, in its typical form, existed throughout a long period of time. This is evident from its occurrence in the Abden Limestone and at Stenton, in beds separated by considerably over 2,000 feet of strata.

From an evolutionary standpoint the most interesting are the cups from the Seafield Tower Limestone. Here we meet an assemblage which are comparable in many ways with *Eupachycrinus calyx* and *Zeacrinus konincki*, with which species our specimens of *Ulocrinus globularis* are closely associated. There can be little doubt, I think, that this horizon marks the metropolis of the crinoids in Lower Carboniferous times, so far as the West Fife area is concerned. I have already given some idea of the number of species which occur in this bed (*Trans. Edin. Geol. Soc.*, vol. x, pt. ii, 1914, pp. 148–60; *Trans. Geol. Soc. Glasgow*, vol. xvi, pt. iii, 1917–18, p. 134; *Trans. Edin. Geol. Soc.*, vol. xi, pt. ii, 1925, p. 275). The period when it was formed was characterized by an exceptional set of physiographic conditions which occurred once only in the history of the Lower Carboniferous in the West Fife region. The conditions then prevailing were eminently well

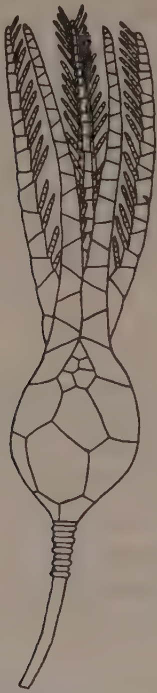
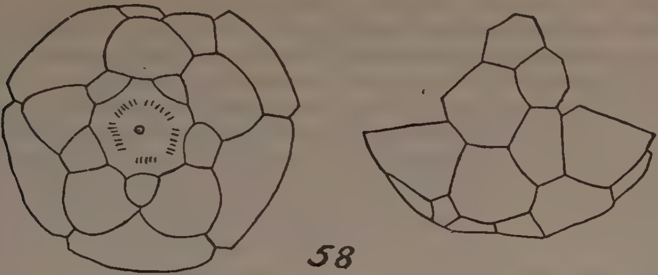


Fig. 57*a*.—*Ulocrinus globularis* de Kon. To show arm structure. $\frac{3}{2}$ natural size.



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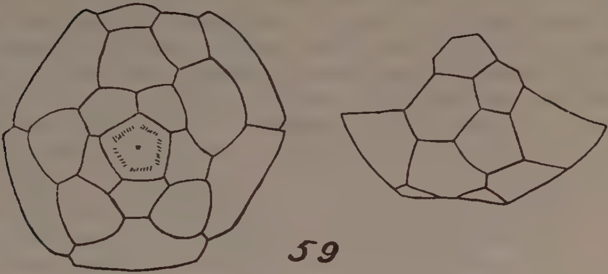

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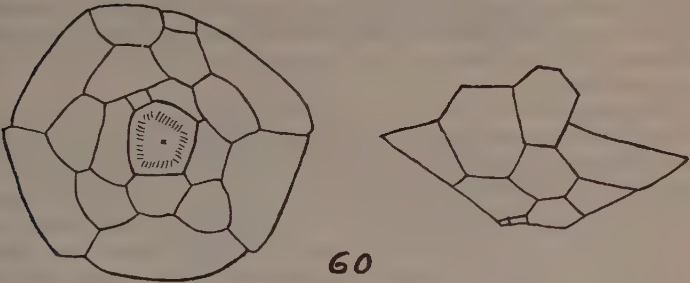

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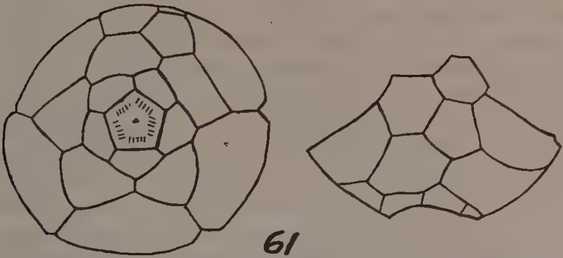
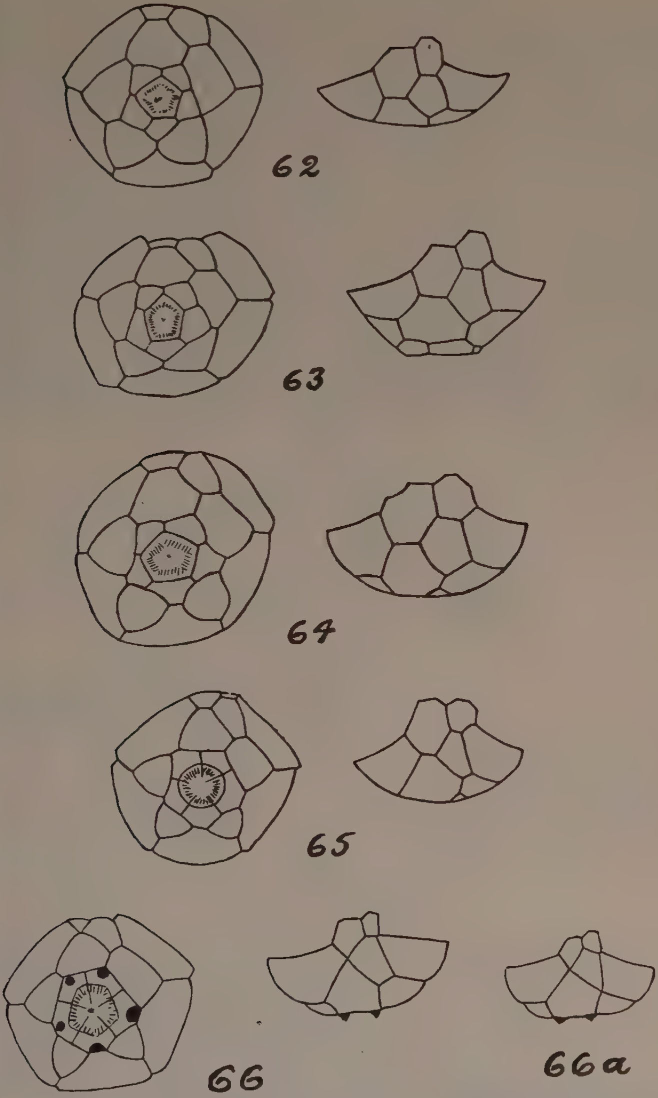


61

Figs. 58–61.—*Hydreionocrinus.* 58, 59, Roscobie; 60, 61, No. 3 bed, Invertiel. $\frac{3}{2}$ natural size.

adapted for the well being and development of many species of crinoids and for their preservation in the fossil state. The full effect of the evolutionary impulses could here come into play and in the case of *Eupachycrinus calyx* and *Zeacrinus konincki* we see in the cups the evidence towards the elimination of the anal plates. In *Ulocrinus globularis*, while the effect is not so pronounced, we also see the same tendency in the eight cups already referred to (Figs. 52 to 57). That the advanced type of anal area was well established in this species long before the period of the Seafield Tower Limestone is clearly shown in the cups from the second Abden Limestone which lies over 100 feet below. The type of cup then evolved, with its advanced anal area, was probably better adapted almost than any other for varying sets of conditions, since it is found in different kinds of sediments in which it is often the only crinoid species. In the second Abden Limestone it is found among the last survivors of a crinoid fauna at the top of the shaly layers which overlie this limestone. There are no other determinable crinoids in this bed, the only other remains being stems and ossicles. In the " Bottom Bed ", Seafield, we again meet the species, this time in a dark shale, the only other crinoid being a cup of indeterminable species. In the Seafield Tower Limestone proper we find it again in increased numbers, this time flourishing side by side with many other crinoid species. Above the Seafield Tower Limestone we find the species again in No. 4 Limestone, this time associated with the rare *Tribrachiocrinus*, the only known occurrence of this genus in this hemisphere. Here it maintains its typical form.

In the same series of strata at St. Monans we meet the species at three different horizons, but none of the beds in this section are precisely of the same lithological character as the Seafield Tower Limestone, so we infer the conditions never were of quite the same nature. In Zone 19 it is the only crinoid species. The shale and cement stone on this horizon were evidently deposited under conditions extremely unfavourable to crinoid life in general, and yet *U. globularis* flourished in considerable numbers. In the other beds at St. Monans and elsewhere in Fife, up to the highest limestone in the Carboniferous Limestone Series, where a determinable crinoid fauna is found, we usually find the species. In all these cases, as we have seen, the advanced type of anal structure is the dominant one. Viewing the Seafield Tower Limestone specimens as a whole, we are perhaps justified in regarding them as a series which show modifications in accordance with the specially favourable conditions prevailing at the time of the deposition of the bed, the extreme forms as to shape as efforts towards some kind of specialization, and the small group of primitive forms, as in this instance, a regressive series towards the more primitive ancestral form, which no doubt existed in the Scottish region long before the advent of second Abden Limestone times.



Figs. 62–6*a*.—*Hydreionocrinus*. 62, Roscobie; 63, Shales overlying "White Limestone", St. Monans Burn; 64–6, 66*a*, No. 3 bed, Invertiel. $\frac{3}{2}$ natural size.

## Arm Structure.

It is a curious fact that among the hundreds of cups of *Ulocrinus globularis* which I have collected from Fife not a single one shows traces of the brachials. Fortunately I have three somewhat crushed crowns from Penton Linns (Geol. Mag., Vol. LXI, 1924, p. 271) which show three of the arms in good detail. From these I have drawn Fig. 57*a*, which gives some idea of this crinoid as it would appear in life. The arms, so far as shown, are uniserial, and consist of a series of cuneiform primibrachs. The pinnules are well shown in one of the specimens. The figure, while correct in so far as these specimens are concerned, shows the arms all round the radius of the cup of nearly equal length and width, but being based only on three specimens must be accepted with some reserve. It is given here merely as an indication of the type of arm structure associated with the species, since, as far as I know, no other British specimens have been found with the arms preserved. In America the arms are unknown (Zittel-Eastman, *Textbook of Palaeontology*, 1913, p. 224).

## Hydreionocrinus.

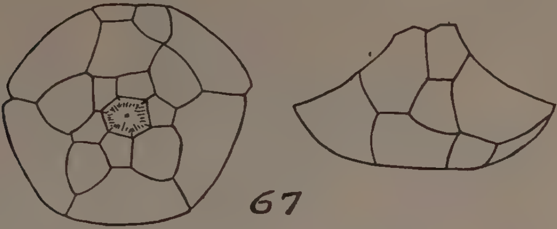
*Localities and number of cups.*

| | |
|---|---|
| Invertiel, No. 3 Bed . . | 39 |
| „ No. 2 Bed . . | 6 |
| Roscobie . . . | 19 |
| Chapel . . . . . | 1 |
| " White Limestone," St. Monans | 65 |
| | 130 |

| | *Primitive Type.* | *Primitive Type A.* | *Advanced Type.* | *Advanced Type A.* |
|---|---|---|---|---|
| Invertiel, No. 1 Bed . . | 36 | 2 | 0 | 0 |
| „ No. 2 Bed . . | 5 | 1 | 0 | 1 |
| Roscobie . . . . | 17 | 0 | 1 | 0 |
| Chapel . . . . . | 1 | 0 | 0 | 0 |
| " White Limestone," St. Monans | 65 | 0 | 0 | 0 |
| | 124 | 4 | 1 | 1 |

## Hydreionocrinus.

The number of cups here dealt with is 130. For our purpose they may be grouped together, but I think there is no doubt that they belong to more than one species. In a paper by Dr. Bather (*Trans. Edin. Geol. Soc.*, vol. x, pt. i, 1911–12, p. 75) he says there are probably two species from Invertiel and Roscobie, although from the text it is not clear how he differentiates between them. In a previous examination of fifty of these cups (*Trans. Geol. Soc. Glasgow*, vol. xvi, pt. iii, 1917–18, p. 383) I said that one might group them broadly into two types, one somewhat bowl-shaped (No. 1 species), and the other rather more expanding or basin-shaped (No. 2 species). In the former the IBB, outside the column



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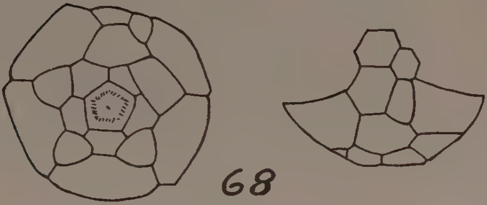

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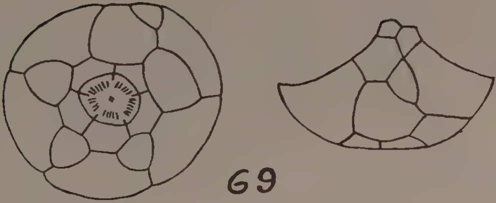

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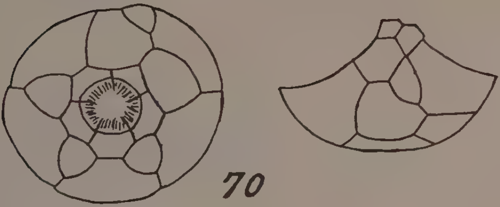

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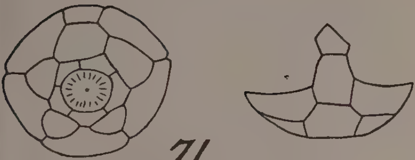

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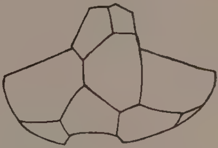

72

FIGS. 67–72.—*Hydreionocrinus.* 67, 68, 70, 71, No. 2 bed, Invertiel; 69, No. 3 bed, Invertiel; 72, Roscobie. $\frac{3}{2}$ natural size.

facet, are irregularly rounded, sometimes highly curved plates and occasionally show a knob or projection which looks like a short stout spine. All plates in cups of this type are very tumid, and in many cases the suture lines are sunk in indentations or grooves. In the more basin-shaped cups, the suture lines are more flush with the plates, the IBB are relatively larger outside column facet, quite flat, and do not show the knobby character. Both types of cups have highly ornamented plates, with fine to coarse granular or tuberculated surfaces. A striking feature of both types of cups from Invertiel and Roscobie is the meeting of one or more of the IBB with the radials, a character which is also seen in the specimen of *H. woodianus* figured by Dr. Bather in paper cited above. In our specimens this occurs in many with all the radials, excepting right post. R, in others it may only be one R, as in Fig. 62, although in this case the right antero-lateral R just touches the right ant. lat. IBB. This is an exceptional case, however, since in the majority of cups two or more of the IBB connect up with the RR, Figs. 58–61, 64–71. This applies only to the cups from Roscobie and Invertiel.

It is quite different with the series from St. Monans, and here, probably, we are dealing with another species. Of the sixty-five cups from the East Fife locality, all have the IBB completely separated from the RR, with the exception of two cups in which only one IB connects with the R. These St. Monans cups are of a rather more elegant form, with finer ornamentation, and remain remarkably constant, not only in shape, but also in the primitive character of the anal area, Fig. 63.

The chief point brought out by the examination of the cups as a whole is the preponderating number which show the primitive type of anal structure. Of course, one notes the usual variation in the size and shape of the RA, especially in the Roscobie and Invertiel cups, but for the majority the plan always remains the same; although in a few cases the lower end of RA tends to narrow, or the anal X is occasionally wedge-shaped at its lower end and almost allows the RA to touch the left post. R, Figs. 66, 66*a*. In such cases it is sometimes difficult to say whether the RA does actually connect with left post. R, or whether the lower end of RA has left right post. B. Beyond these are four specimens which show the complete detachment of RA from right post. B (Figs. 67, 68, 69, 70), and these may be likened to the group Normal A of *Eupachycrinus calyx*.

A specimen which is of interest is that shown on Fig. 72, since in its anal structure it bears some resemblance to the figure of *Poteriocrinus granulosus* given by Phillips in *Geology of Yorkshire*, pl. iv, fig. 8. Phillips records the specimen from "near Kirkaldy", and it is quite probable that it came from Invertiel, since the quarry was being worked at the date when Phillips wrote. His description of the cup is "hemispherical, delicately granulose, sutures

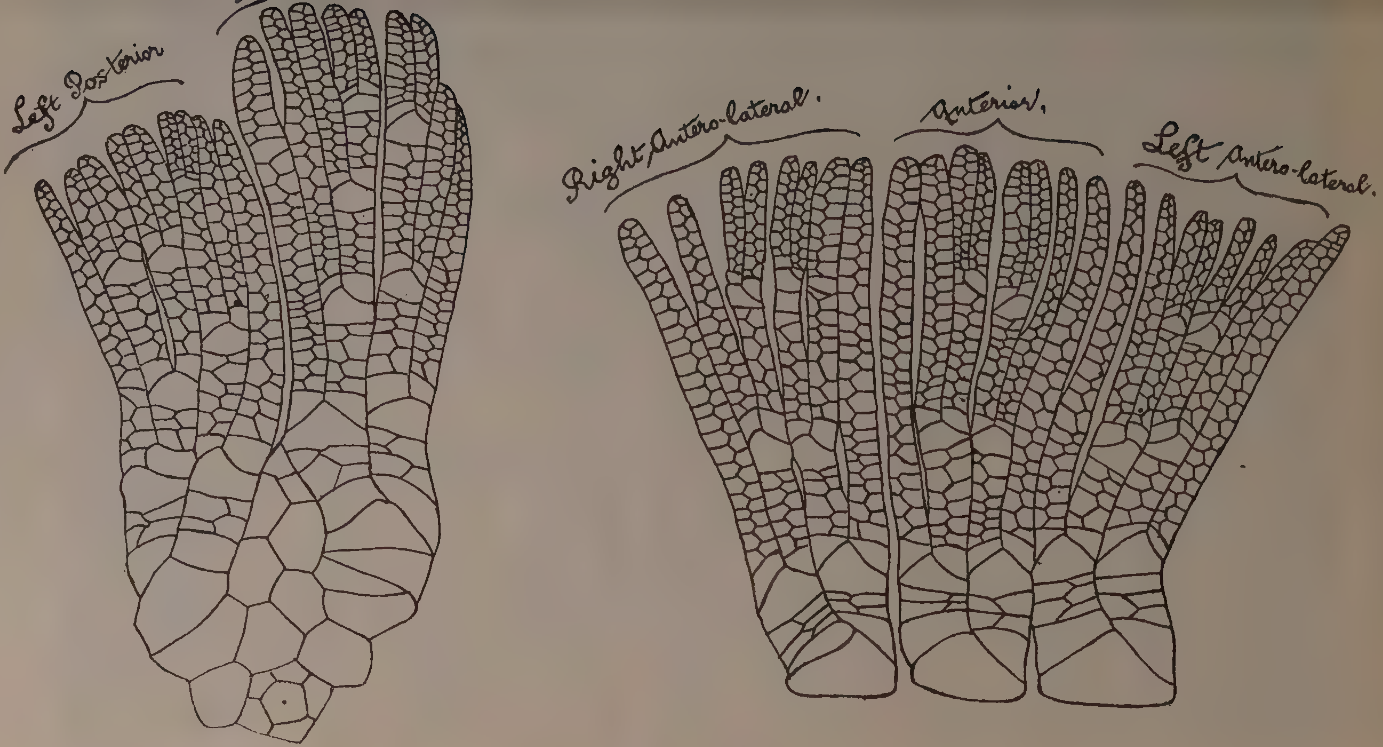

FIG. 73.—*Hydreionocrinus*, species allied to *H. woodianus* de Kon. Specimen No. 1538 author's collection from No. 3 bed, Invertiel. $\frac{3}{2}$ natural size.

grooved ". In Phillips' fig. 8 the RA occupies a position not unlike our Fig. 72, although in Phillips' figure x and r t are lower down in the cup. This, of course, may only have been an individual variation. We have only one specimen of the nature of Fig. 71, and it may be observed that the RA is an exceedingly long plate, extending well out beyond the radial circlet.

Taking the series of *Hydreionocrinus* as a whole, the primitive type of anal area was of a comparatively stable character, and the evidence towards reduction of RA is slight compared with *Eupachycrinus calyx.* Such variations as affected the cups appear, in the Roscobie and Invertiel specimens, to have been mainly in the direction of the meeting of the IBB with the RR. The St. Monans specimens are very uniform in general characters, and in this respect the nearest described species with which they can be compared is *Poteriocrinus phillipsianus* de Kon. and Le Hon., referred provisionally to *Hydreionocrinus* by Dr. Bather (*Trans. Edin. Geol. Soc.*, vol. x, pt. i, 1911–12, p. 71).

The differentiation of all these cups into species is, however, a matter for further research, and will not be cleared up until the crowns are fully studied. In my collection from Roscobie, Invertiel, and St. Monans are a series of crowns with the help of which it is hoped at a future date to throw some light on the subject. Meantime I give a sketch (Fig. 73) of a species allied to *Hydreionocrinus woodianus*, which shows the somewhat complicated arm branching associated with the genus and is the first complete British crown to be so figured.

COMPARISON OF THE FOUR GROUPS OF CUPS.

| | *Eupachycrinus calyx.* | *Zeacrinus konincki.* | *Ulocrinus globularis.* | *Hydreionocrinus.* |
|---|---|---|---|---|
| Primitive Type . | 771 | 49 | 54 | 124 |
| ,, A . | 40 | 5 | 0 | 4 |
| Advanced Type . | 115 | 231 | 480 | 1 |
| ,, A . | 67 | 56 | 8 | 1 |
| Other types . . | 3 | 0 | 0 | 0 |
| Abnormal . . | 3 | 1 | 0 | 0 |
| Symmetrical . . | 1 | 0 | 0 | 0 |
| | 1,000 | 342 | 542 | 130 |

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# Vesuvianite and Grossular as Products of Regional Metamorphism.

By C. E. TILLEY.

(PLATE X.)

THE chemical environment of vesuvianite and grossular is typically revealed in their associated minerals, calcite, diopside, scapolite, and wollastonite, characteristically developed under the physical conditions prevailing in thermal metamorphism.

Grossular-vesuvianite assemblages are also found associated with serpentine masses, where they appear to be formed essentially by pneumatolytic action or contact metasomatism, as in the European localities described by Weinschenk, Murgoci, and others. Grossular itself is also known as a product of saussuritization. Lastly as constituents of Kata-zone rocks, these minerals may occur in carbonate sediments, frequently associated with pelitic assemblages of the sillimanite zone.

Much less common, however, is the development of these minerals—to judge from investigations hitherto carried out—as products of regional metamorphism of medium grade.

The Loch Tay limestone horizon of Perthshire provides excellent material in which such assemblages can be studied, and inasmuch as the associated pelitic sediments have been zoned by metamorphic survey a close standard of comparison for the assemblages of the calcareous rocks is provided.

The Loch Tay limestone in Argyllshire and Perthshire is essentially a calcitic type, as indicated not only by chemical analyses, but also by the mineralogical composition of its metamorphic representatives. Three available analyses show the following lime and magnesia percentages: (1) CaO 47·51, MgO 0·25; (2) CaO 37·21, MgO 0·35; (3) CaO 31·01, MgO 4·09. (1) and (2) Glen Sluan, Argyllshire; (3) $\frac{2}{3}$ mile north-west Loch na Moine, Pitlochry. In Perthshire and Argyllshire the limestone horizon is enclosed within the biotite and almandine zones.

The presence of vesuvianite and grossular as constituents of the regionally metamorphosed limestones was first recognized by Teall (1897) from the Cowal area, where they are now known to be developed within the almandine zone.

The following short account refers to the mineralogical assemblages of the Loch Tay limestone, principally from Perthshire, but extending from the biotite zone to well within the almandine zone, chiefly over a tract from Balquhidder to the vicinity of Garth, north of Kenmore.

*Biotite Zone.*—Loch Tay limestone: Constituents calcite, quartz, albite, biotite, muscovite, chlorite, together with iron ores and some graphitic material, the latter enclosed either in calcite or quartz.

*Almandine Zone.*—Loch Tay limestone: At the southern edge of this zone the constituents are similar to those noted above. Zoisite may become an important constituent and is perhaps also generated in the biotite zone. Both zoisite $\alpha$ (optic axial plane // to 010) and zoisite $\beta$ occur, the latter more commonly, and building long prisms with optic axial plane perpendicular to the 010 cleavage in the plane 001. Anomalous interference tints are absent in the latter. Under a higher grade of metamorphism and with a further advance into the almandine zone, amphiboles, clinozoisite-epidote, and ultimately grossular, vesuvianite, and diopside enter. The outcrops of Loch Tay limestone on the north-west side of Loch Tay, from Killin to Garth, north of Kenmore, provide excellent material for the study of these assemblages. At Tirarthur and other places the limestone contains aggregates weathering out in nodular form of vesuvianite-grossular-diopside.

Typical calc-silicate assemblages from the region of Killin to Garth are: (1) Diopside, zoisite (and/or clinozoisite), potash-felspar, calcite; (2) grossular, vesuvianite, diopside, potash-felspar. In addition albite is frequently present, while zoisite and clinozoisite may occur in association, together or with vesuvianite.

Noteworthy at this stage of metamorphism in these assemblages is the complete absence of muscovite, from which the abundant potash-felspar—often as microline—is in part generated.

Biotite is less common, and plagioclase is represented only by the sodic end member, albite or oligoclase.

In the associated calcareous pelitic sediments, green hornblende is developed at this stage, giving rise to zoisite or clinozoisite-garnet-hornblende schists, or granulites.

In the calc-silicate assemblages vesuvianite occurs in long octagonal prisms of honey yellow colour, showing the forms *a* (100), *m* (110), *c* (001), sometimes *p* (111), and also steeply inclined pyramids. Cleavage poor (110). *a* (100) is more prominently developed than *m* (110). The mineral shows normal interference tints and is always optically negative. $\Delta = \cdot 006$; pleochroism noticeable; $\epsilon =$ yellow; $\omega =$ faint yellow to colourless. Absorption $\epsilon > \omega$. The colour may be unevenly distributed. Grossular when idioblastic has typically the (110) development, though (211) is also observed. Whether large or small, the grains are uniformly isotropic. As with vesuvianite, so with grossular, inclusions may be abundant, yielding a sieve texture, the common enclosures being calcite, quartz, or diopside.

From the data now available we may construct the course of metamorphism in the Highland region in these calcareous rocks, the representative assemblages with advancing metamorphism being as follows:—

| | | |
|---|---|---|
| 1. Quartz-muscovite-chlorite limestones | Chlorite zone. | |
| 2. Zoisite limestones [muscovite, biotite] | Biotite zone. | Almandine zone. |
| 3. Tremolite-actinolite limestones [Clinozoisite–epidote] | | |
| 4. Diopside limestones[1] [Grossular, vesuvianite, potash felspar] | | |

It is of interest to compare the higher grade assemblages of these calcareous rocks with the isochemical assemblages of thermal metamorphism. Conspicuous differences can be recognized. The former are differentiated by the presence of zoisite and clinozoisite, potash-felspar as microcline compared with orthoclase in contact metamorphism, and the absence of anorthite-rich plagioclase in the vesuvianite-free assemblages. Individual minerals as grossular and vesuvianite also show differences in that optical anomalies are absent. On the other hand, considering the evidence of stress metamorphism seen in the associated pelitic sediments, the occurrence of grossular, vesuvianite, and potash felspar so typical of thermal metamorphism in these rocks is somewhat remarkable.

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[1] Wollastonite as a constituent of a grossular-vesuvianite-diopside-microcline assemblage is once recorded from the limestone of the Carie Burn.

The examples now studied show some analogy to the described occurrence[1] of forsterite and spinel-bearing marbles in association with garnet para-gneisses in which the influence of shearing stress is seen in the marked schistosity and the elongation of individual garnet crystals.

The maximum value of shearing stress is a function of the temperature, but the value for a given temperature is also a function of the composition of the rock subject to the stress. In the case to which allusion has just been made, it may be noted: "That at a given temperature the upper limit of shearing stress is lower for the carbonate rock than for the more rigid quartzo-felspathic type, seems undoubted, and the essential factor in this behaviour is the ease with which the carbonate minerals recrystallize and the consequent tendency to a viscous flow limiting the range of shearing stress."[2]

It is to such a cause that we may look for explanation of the seemingly anomalous appearance of grossular, vesuvianite, and potash-felspar in a region of stress metamorphism. In reality the mineral assemblages of the carbonate rocks of the Loch Tay region show features of both contact and regional type. In the presence of the zoisite-epidote group of minerals and microcline in place of orthoclase we may recognize a distinction from the higher grades of thermal metamorphism, a distinction which is probably to be attributed to a lower temperature and the presence of some of the stress element which becomes dominant in the associated pelitic sediments.

It would be of great interest if the progressive metamorphism of a group of dolomitic sediments could be traced through varying grades of metamorphism. Study of the thermal metamorphism of these rocks shows quite clearly that dolomite reacts with siliceous and aluminous material at an earlier stage than calcite. Some eatures, however, of certain carbonate members of the Ben Lawers chists of the Highland region suggest that this rule is not necessarily igidly adhered to under stress metamorphism. Among these ediments we find that dolomite is found in close association with linozoisite or epidote, the implication being that epidote is formed rom calcite before dolomite reacts with its associated minerals.

A beginning in the study of the progressive metamorphism of dolomites in stress zones has already been made by Kolderup in

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[1] Geol. Mag., Vol. LVIII, 1921, p. 307.

[2] Loc. cit.

Western Norway,[1] and a similar early generation of epidote has been noted by this investigator. With advancing metamorphism, hornblende and then diopside appear.

The occurrence of microcline and garnet is attributed to magmatic injection, and with reference to the former mineral Kolderup is apparently of the opinion that other occurrences described in the literature have a similar source. For the Highland region no such origin is possible, and one is tempted to inquire whether Kolderup has supplied incontrovertible evidence for his own examples.

The writer is much indebted to Dr. G. L. Elles for the free use of her collection of rocks and slides from the Loch Tay area.

### EXPLANATION OF PLATE X.

FIG. 1.—Vesuvianite-grossular-diopside rock, metamorphosed Loch Tay limestone, Tirarthur, Loch Tay, magnified 25 diameters. Porphyroblasts of vesuvianite in a ground of grossular, diopside, potash-felspar, and quartz.

FIG. 2.—Vesuvianite-diopside-zoisite rock, metamorphosed Loch Tay limestone, quarry east of Keltnie Burn, near Kenmore (Slice No. 17482, Sedgwick Museum collection), magnified 25 diameters. Porphyroblasts of vesuvianite and zoisite (right) in a ground of diopside, potash-felspar, calcite, and quartz.

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# The Structure and Development of *Sphenotrochus crispus*, and Notes on Aporose Morphology.

By T. A. RYDER, B.Sc., Ph.D., F.G.S.

## INTRODUCTION.

APOROSE corals have, with few exceptions, received little attention in Britain since the publication of works by P. M. Duncan and R. F. Tomes, during the latter half of last century.[2] The newer methods of investigation by means of thin slices and serial sectioning, so successfully employed by Drs. Stanley Smith and W. D. Lang, and others, in the Rugosa, were not then in use, and so very little is known of the internal structures—the only basis for classification and comparison—or of the developmental stages of the Aporosa.

This paper, which deals with *Sphenotrochus crispus* Ed. and Haime is the second [3] of a series in which the author hopes to describe the structure and development of selected species. It is advisable

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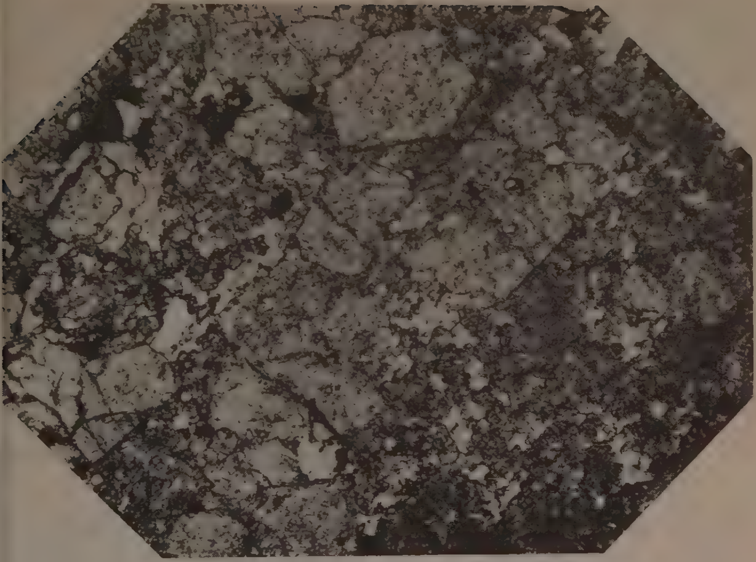
[1] N. H. Kolderup, "Die Injektionsmetamorphose des Dolomitmarmors im Mögstergebiet in westlichen Norwegen," *Bergens Museums Aarbok*, 1923–4, Naturvidensk. raekke, Nr. 1.

[2] P. Martin Duncan, *Supplement to Monograph of the British Fossil Corals*, 1866–72, and various papers in the GEOL. MAG. and *Quart. Journ. Geol. Soc.*, 1863–90, and R. F. Tomes, papers in the same, 1884–99.

[3] The first, "The Structure and Development of *Holocystis* Ed. and Haime," was published in the GEOL. MAG., Vol. LXIV, 1927, pp. 119–22.



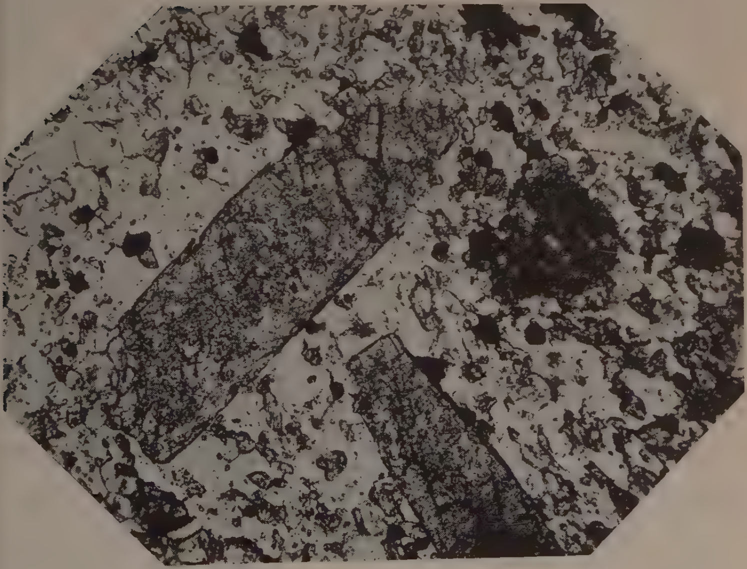


FIG. 1.—VESUVIANITE-GROSSULAR-DIOPSIDE ROCK.
,, 2.—VESUVIANITE-DIOPSIDE ZOISITE ROCK.

[*To face p. 376.*

to preface the remarks about *Sphenotrochus* by a short account of the skeletal elements of an Aporose coral, since there is some confusion in the use of certain terms, and more especially is this the case with those terms that have been applied both to the Rugosa and the Aporosa.

The author tenders his thanks to Dr. A. E. Trueman for access to and use of material in the Reader Collection of the Geological Department of University College, Swansea, and to Dr. Stanley Smith for valuable advice and criticism throughout the course of the research, which has been made possible by the aid of a grant from the Royal Society, to the President and Council of which thanks are also tendered.

## SKELETAL ELEMENTS OF AN APOROSE CORAL.

The structures of an Aporose coral may be divided into: (*a*) Essential or Unit structures, which are always present; (*b*) Secondary or Derived structures, which may or may not be present.

### (*a*) *Essential Structures.*

1. *Septa* (Text-Fig. 1).—The septa of Aporose corals are inserted in sixes or multiples of six, and are, normally, arranged radially. The first six septa to be inserted are the primary cycle, the second six, each of which is inserted one between each pair of primaries, belong to the secondary cycle, and so on. Since new septa are always inserted between each pair of older septa, there will be twelve in the tertiary cycle, and twenty-four in the fourth cycle, if that is developed.[1] All the septa lying between two primaries are said to form a system,[2] therefore, in a coral which has four cycles, a system would consist of one of the secondary cycle, two of the tertiary, and four of the quaternary, or seven in all, and as there would be six systems in the corallite, there would thus be $(6 \times 7) + 6$ primary septa, i.e. 48 septa present in all.

### (*b*) *Secondary Structures.*

1. *Epitheca.*—This is the name given to an outer or mural investment, which may or may not be present, when it is it may, however, be confined to the proximal part of the corallum, e.g. *Montlivaltia haimei.* When the epitheca is absent, the outer edges of the septa are naked and stand out as ridges, or costae,[3] on the outer surface of the coral, and they are then said to be exsert.

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[1] It sometimes happens that owing to irregularity of growth or other causes the later cycles of septa are incomplete, e.g. in *Holocystis elegans* (Fitton) the tertiary cycle is not complete, only four or five being developed.

[2] See P. M. Duncan, "Supplement to British Fossil Corals," *Pal. Soc. Mono.*, pp. 8–9.

[3] These ridges should not be confused with those found on Rugose corals, which have a different origin, being inter-septal, i.e. they correspond to the gaps between the septa and not to the edges of the septa themselves, as above.

2. *Theca.*—This is an inner wall-like structure formed between the septa near their outer edges and is usually made up by the deposition of tissue between already thickened portions of the septa.

3. *Columella.*—This term is applied to a simple, axial structure, which may or may not be present, and which may be of independent formation, or which may often be formed by the fusion of the inner edges of the septa, aided by the deposition of stereoplasmic tissue. An axial structure, analogous to the central column of such a Rugose coral as *Dibunophyllum*, does not appear to be ever present in an Aporose species.

4. *Tabulae.*—True tabulae, i.e. more or less horizontal diaphragms crossing the visceral cavity, are very rare in the Aporosa, but, nevertheless, are sometimes found. Occasionally, approximately horizontal, spine-like processes arise from the septa and may be reinforced by secondary tissue, but these must not be confused with the above.

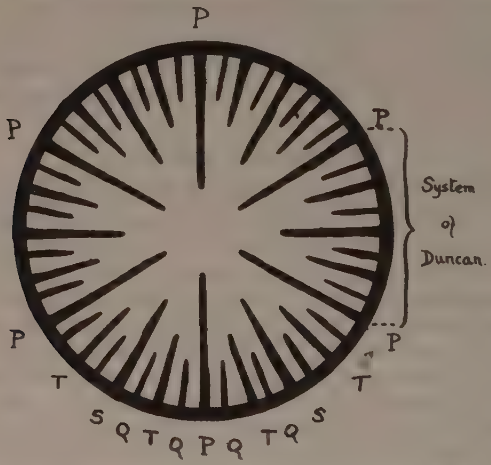

Fig. 1.—Diagrammatic transverse section of an Aporose coral, to show septal plan. Primary, secondary, tertiary, and quaternary septa are shown as of diminishing size, but this does not imply that the metasepta do not develop to the same extent as do the primary.

### Sphenotrochus Ed. and Haime.

Milne Edwards and Jules Haime, *Ann. des Sc. Nat.*, 3me serie, tom. ix, 1848, p. 297.

The genus *Sphenotrochus* was founded by Edwards and Haime in 1848 to include two species of simple corals from the Tertiary Beds, *Turbinolia crispa* Lamarck and *Turbinolia intermedia* Münster. These authors made *S. crispus* the type of their new genus. The species of *Sphenotrochus* are interesting, on account of their oval cross-section and their peculiar type of costae.

*Sphenotrochus crispus* Ed. and Haime, loc. cit., p. 241.

### *External Characters.*

*S. crispus* is a simple Aporose coral, which is more or less conical n shape ; the cross-section is elliptical in outline at all stages of rowth, and the corallum is erect, with no dilation at the base or roximal end, i.e. it is nonpediculate. No epitheca is developed, herefore the septa are exsert. The costae are plain and nornamented in early stages but later become more or less crispate n appearance. The calyx is shallow, and in it are seen twenty-four epta, that is three cycla are developed. The primary septa reach he columella, which is elongated in the direction of the long axis f the coral. The dimensions of an average corallite are as follows : Height 6 mm., longer axis of calice 6 mm., shorter axis 4 mm. As consequence of the shape of the calyx, the coral does not present he radial appearance usually characteristic of members of the Aporosa.

### *Internal Characters* (Text-Fig. 2).

*Ephebic Stage* (Text-Fig. 2, 2 and 4).—Transverse sections of this pecies show twenty-four septa arranged in six systems, and there re three cycla developed. These septa are not arranged radially, out are more or less bilaterally disposed, this is due to the elliptical hape of the cross-section. The septa of the primary cycle usually each the columella and their inner edges are often fused to it, as are lso those two secondary septa which lie one at each end of the longer xis of the corallite (Text-Fig. 2, 2*d*). This arrangement helps to give somethat cruciform appearance to the section. The other septa of the secondary cycle are usually slightly shorter, whilst hose of the third cycle are about one-half to two-thirds the length of the primary. Short, spiny, carinae-like[1] processes are developed on most of the septa irrespective of the cycle to which they belong.

The columella is very variable in appearance and size, but is ormally a somewhat spongy plate-like structure, which is elongated n the direction of the long axis of the corallite. The theca is very trongly marked, and is reinforced by the deposition of secondary issue ; it does not continue upwards to the distal edges of the septa, herefore is not seen in calicular sections. There is no transverse issue present.

### *Note on the Costae* (Text-Fig. 2, 3).

In early stages the peripheral edges of the septa, i.e. the costae, re plain and vertical ridges, but as growth proceeds, however, they ecome dentate and flexuous, or, as Edwards and Haime described t, crispate. This ornamentation appears to begin when the third ycle of septa has been inserted, and becomes more and more marked as the coral grows, until in advanced forms the costae are very crispate.[1]

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[1] These must not be confused with the true carinae, that is arched ascendant idges developed on the sides of the septa in certain Rugose genera, e.g. *eliophyllum* Hall.

### *Ontogeny.*

*Brephic Stage* (Text-Fig. 2, 1).—This stage, in which only the six primary septa are present in the calicle, is an extremely short one, and, in fact, on the exterior of the proximal end of the corallite. A number of specimens with well-preserved tips have been examined,

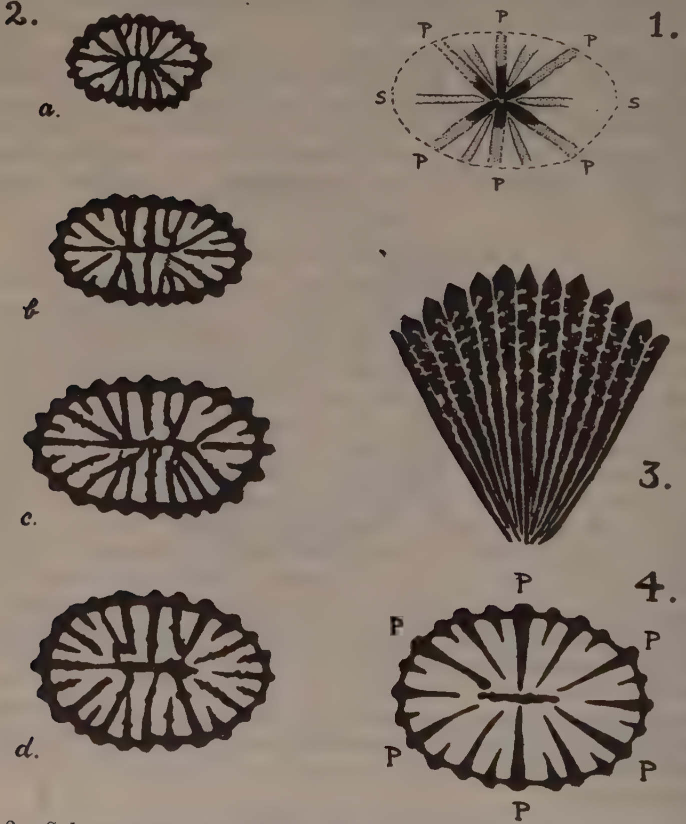

FIG. 2.—*Sphenotrochus crispus* Ed. and Haime. 1, Brephic and Early Neanic Stages, exterior aspect of corallite, the stages being too condensed to make a section. Only primary (P) and secondary septa (S) shown. 2*a*–*d*, Developmental stages of a single corallite; transverse sections; *a* and *b*, Neanic; *c* and *d*, Ephebic. 3, exterior aspect of side of corallite, to show costal ornamentation. 4, Diagrammatic view of calyx to show arrangement of septa and columella (P = primary septum). All figures multiplied 5 diameters, except 1, which is × 10 diameters.

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[1] A somewhat similar type of costal ornamentation has been described in *Levipalifer orientalis* by T. Wayland Vaughan, *Proc. United States Museum*, vol. xxii, 1900, p. 201.

but so brief is the stage that it has been found impossible to prepare a section of it.

*Early Neanic Stage* (Text-Fig. 2, 1).—Insertion of the secondary cycle takes place almost immediately after the first cycle is laid down. All the primary septa and usually all the secondary reach the centre, and their inner edges are fused to form a central mass, the beginnings of the columella. The costae are still plain and unornamented, and no carinae-like processes are present.

*Later Neanic Stage* (Text-Fig. 2, 2).—The insertion of the third and last cycle soon follows and completes the full complement of septa. Carinae-like processes begin to develop, and the costae become flexuous. All of the primary and many of the secondary septa are still united to the columella, which is often reinforced with stereoplasmic tissue, but as development proceeds, they gradually recede from it and leave it as an elongated spongy structure.

The last stage passes, with further contemporaneous developments of carinae-like processes, columella and costal ornamentation, into the ephebic described above.

*Locality and Horizon.*—All the material examined for this paper is in the Reader Collection of the Geological Department, University College, Swansea, and was collected from the Lutetian Beds (Upper Eocene) of Grigon, about 25 miles west of Dijon, France.

# REVIEWS.

Bauxite. By C. S. Fox. pp. xii + 312, with 20 photographs as plates, 9 figures, and 6 maps. London: Crosby Lockwood and Son, 1927. Price 30*s*.

As the author remarks in his preface, there was room for a book on bauxite dealing with the geological aspects of its occurrence and distribution, as well as the difficult problem of its origin. From extensive field experience, Mr. Fox is well qualified to write such a book, and on the whole he has done his task well and produced a volume of great value, although suffering from certain minor blemishes which may be mentioned first. The proof-reading has evidently been careless, and very many proper names are misspelt, a peculiarly irritating defect. The type, paper, and illustrations are very good, perhaps too good, as the price is very high.

The author discusses ably, and with evident knowledge of recent work on the rôle of colloids in geology, the whole broad question of the origin of the laterite-bauxite type of deposit, and comes eventually to what may be conveniently summarized as the "monsoon" theory, which is too well known to need re-statement here. A special class is made, however, for what he always calls the "terra rosa" type (terra rossa), which is to be regarded as a residual mud from aluminous limestones. It may be suggested as a minor point that a little too much attention is paid to an attempt to apply exact mineralogical names to the hydrated ferric oxides. It is now generally agreed that there is no such thing as "limonite", as a mineral species, although göthite seems to be well established. In the description of some micro-photographs on p. 41, it is not clear what is meant by "crossed nicols, natural light".

The sixth chapter, which is the longest in the book (73 pages), is taken up by a description of the bauxite occurrences of the world. As is only natural those of India are dealt with at very considerable length. The last four chapters, on the mining, technology, metallurgy, and marketing of bauxite and its products, are not within the province of a geological review, though of much interest from many points of view.

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PHYSICO-CHEMICAL GEOLOGY. By R. H. RASTALL. pp. vii + 248, with 62 figs. London: Edward Arnold and Co., 1927. Price 15*s*.

A LARGE number of students will doubtless be grateful to Dr. Rastall for this book. Modern research into problems of petrology, ore-deposition and the constitution of the earth's crust is becoming increasingly dependent on the solution of physico-chemical problems. How far experimental work in the laboratory, limited as it is by attainable conditions and by the number of components of the system under investigation, can assist in the interpretation of rock-history remains still to be proved, but the valuable work accomplished by the staff of the Geophysical Laboratory of Washington, as well as other workers, has shown that much can be done. The searching and perusal of the records of these investigations are often laborious and sometimes difficult tasks for the average student. Moreover, the authors of papers must of necessity assume a certain standard of knowledge of earlier work on the part of their readers.

Dr. Rastall's book will be of much service to younger workers, for it is obviously written with a teacher's instinct and appreciation of the student's difficulties. In the earlier chapters, the Author treats of physico-chemical problems such as equilibria, changes of state and solution, in the main in a simple style. He does not scorn the device (for which we may be grateful) of inserting first a simple diagram and then repeating it with the introduction of additional factors. The succeeding chapters include a discussion of isomorphism, solid solution, polymorphism, and inversion, well-known examples of mineral associations being used as illustrations. The difficulty of compressing much matter into a small space has inevitably led to such brevity in places that lucidity runs the risk of being sacrificed. Our physico-chemical friends may object, for example, to the definition of a condensed system (p. 19) or to the brief consideration of the phase-rule and to the explanation of the behaviour of calcium carbonate (p. 20). Ambiguities have arisen, probably as a result of brevity, on p. 6 (line 24, "reverse process" and line 39, "equal energy"), p. 24, "negative pressure," and p. 56 (line 5, "general rule"). Modifications, leading to greater precision, might also be made in figs. 3 and 6. Apart from these and other debatable matters, a few slips should be corrected in future editions (p. 17, "water" for, presumably, "winter"; p. 18, triple point of water + 0·007° C.).

The chapters following the general exposition deal with the applications of the principles outlined. They are concerned with the origin and composition of the igneous rocks, the processes of metamorphism and weathering, and the formation of salt-deposits and ore-bodies. A chapter is also devoted to the consideration of refractory materials from the point of view of the stability-relations of silica, lime, alumina, etc. A final chapter on colloids in geology is obviously marked by restraint; while the Author is doubtless right in adopting a cautious attitude, a reference to Dr. H. C. Boydell's recent paper [1] might have been of interest to students.

Altogether, in view of the extent and difficulties of the subject, the Author deserves our thanks for this book, which furnishes students with a large quantity of information for the moderate price of 15*s*.

# CORRESPONDENCE.

## A RESCUED COLLECTION.

Sir,—As illustrating how labours and valuable material have been lost in the past, it may interest your older readers to know that the almost unique collection of Chalk fossils made by the late James Fox, of Stamford Hill, N., part of which was exhibited at the London Geologists' Association Conversazione on 4th November, 1892, has been rescued and secured from oblivion.

Last April a kind friend drew my attention to the fact that there was a "very fine collection of Chalk fossils" at a certain antique furniture dealer's shop in East London. It had been lying there for nearly three years and *had twice before been offered for sale* in London sale-rooms, but had not found a sufficiently high bidder. Fortunately I was able to acquire it.

The collection was made chiefly from the *Micraster cor-anguinum* zone at Northfleet, Charlton, and Lewes. (The Charlton pits were worked when I resided in Woolwich 1877–83, but were from then closed down owing to building operations.) The introduction of mechanical quarriers makes it increasingly difficult to obtain perfect specimens. It is impossible to conceive greater skill in developing the beautiful Corals, Cidaridæ, Asteroideæ, *Spondylus spinosus*, and fish remains, as well as the collection in general.

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[1] *Trans. Inst. Min. and Metall.*, vol. 34, 1925.

The various specimens have now found final resting-places in the British Museum, the Universities of Glasgow, Liverpool, and Reading, and Eastgate House Museum, Rochester.

Yours faithfully,
G. E. Dibley.

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## THE CARLISLE BASIN.

Sir,—The courteous criticism by Messrs. Dixon and Trotter of my review of the Carlisle Memoir (Geological Magazine, Vol. LXIII, 1926, pp. 377–9) states the remaining issue clearly. I am glad that they reject the conclusion that the gypseous shales at Abbeytown are a series not elsewhere seen, which provoked my paper (Geological Magazine, 1915, pp. 241–9), as it seemed to have a misleading influence on the interpretation of both the Solway Basin and the Isle of Man. Messrs. Dixon and Trotter avoid the correlation of the gypseous shales at Abbeytown with those south of Carlisle by explaining them as the thickened and changed extension of the Stanwix Marls. Certain resemblances of the sandstone at the bottom of the Abbeytown bore and the Kirklinton Sandstone had forced consideration of that possibility on Holmes and myself. Holmes scouted that idea. The beds at Abbeytown are shales with many layers of gypsum, and one occurrence of salt, and no limestone, and are 746 feet thick. The Stanwix beds are marls with thin beds of limestone without either gypsum or salt, and according to Holmes are " extremely thin ". The Survey Carlisle Memoir (1926, pp. 23, 28) reminds us that in these beds colour is an unreliable guide, but it is not without value, though less important than chemical composition, in which the Abbeytown shales and Stanwix Marls are strikingly different. The evidence for Holmes' Dalton Fault may be small, but that for the Cummersdale Fault appears even less convincing. I followed Holmes in his interpretation of the facts of the Orton bore, but its record of 1781 is too indefinite for much weight to be placed on it. The dismissal of Holmes' Upper Gypseous Shale is an important advance; but the tradition left by Holmes' view will probably delay settlement of the further issue until another bore reveals more evidence. Meanwhile I regard the general structure of the Solway Basin as fitting the correlation of the gypseous shales at Abbeytown and Carlisle in spite of the more varied colours found at Abbeytown.

J. W. Gregory.

*18th May, 1927.*